MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 95 No. 4

1935 FEBRUARY 8

ANNUAL GENERAL MEETING

Prof. F. J. M. Stratton, President, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The President announced that Professor Henry Norris Russell would deliver the George Darwin Lecture at the Ordinary Meeting of the Society on June 14, taking as his subject "The Analysis of Spectra and its Application in Astronomy."

The Report of the Auditors was read, and is given on p. 311.

A vote of thanks to the Auditors was proposed and carried unanimously.

The following motion was proposed by the Secretaries and carried unanimously :—

"That the action of the Council in agreeing to the disposal of certain duplicate books in the library be approved by this Meeting."

The Annual Report of the Council was partly read.

The Address on the award of the Gold Medal was delivered by the President, after which the Gold Medal was presented to Professor E. A. Milne, to whom it had been awarded for his work on Radiative Equilibrium and Theory of Stellar Atmospheres (see p. 421).

The President then delivered an Address on the award of the Jackson-Gwilt Medal and Gift, after which the Medal was handed to the Foreign Secretary for transmission to Mr. W. F. Gale, to whom it had been awarded for his discoveries of comets and his work for astronomy in New South Wales (see p. 429).

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the Report of the Auditors and the President's Addresses. A vote of thanks to the President for his Addresses was also proposed and carried unanimously.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 430.

During an interval Dr. Steavenson showed slides which had been added to the Society's series during the past year.

The thanks of the Meeting were given to the retiring members of Council. Special reference was made to Mr. Reynolds's services as Treasurer since 1929.

It was proposed by the Secretaries, and carried, that the thanks of the Meeting be given to referees of papers.

The thanks of the Meeting were also given to the Scrutineers of the ballot.

The election by the Council of the following Fellows was duly confirmed :—

Arthur Beer, Ph.D., Solar Physics Observatory, Cambridge;
William Gee Bickley, D.Sc., 141 Byrne Road, London, S.W. 12;
William Fitkin Muckle, A.M.Inst.C.E., Asst. Civil Engineer, Port of London Authority, Haddon, Shepherds Lane, Dartford Heath, Kent;
Mrs. Vera Reade, Khandala, 12 Gillian Park Road, Sutton, Surrey;
Sadanand Waman Shiveshwarkar, B.A., Sidney Sussex College, Cambridge ; and
John Davis Williams, Steward Observatory, Tucson, Arizona, U.S.A.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

Mrs. Frances Draper, 4 Whitehall Court, London, S.W. 1 (proposed by R. Inwards) ;
Y. Iba, Ohte, Kobe, Japan (proposed by H. Shapley) ;
Inigo Jones, Director of the Cromanshurst Solar Observatory, Queensland, Australia (proposed by R. B. Bousfield) ;

Reginald Victor Jones, Ph.D., University Observatory, Oxford (proposed by H. H. Plaskett) ;

John Pickston, B.Sc., 15 Stanley Street, Brighouse, Yorks (proposed by W. Porthouse) ;

Charles Frederick Ortmann Smith, 22 Inverleith Gardens, Edinburgh (proposed by J. M'D. Field) ;

Henry John Spooner, M.I.Mech.E., A.M.Inst.C.E., F.G.S., 5 St. George's Terrace, Regent's Park, London, N.W. 1 (proposed by R. Inwards) ; and

Mrs. Ruby Ta' Bois, Winfield, 33 High Road, Woodford Green, Essex (proposed by A. P. Freeman).

The following election, announced 1934 February 9, is void :—

Lieut. V. O. W. Peters, R.N.R., 36 Connought Road, Hong Kong, China.

REPORT OF THE COUNCIL TO THE HUNDRED AND FIFTEENTH ANNUAL GENERAL MEETING OF THE SOCIETY.

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Honorary Member	Fellows		Associates	Total
				Compounders	Annual Subscribers		
1933 December 31	1	4	1	221	680	48	955
Since elected	...	...	...	...	+25	+2	...
Deceased	...	...	...	−6	−13	−5	...
Resigned	...	...	...	...	−13	...	...
Since compounded	...	...	...	+2	− 2	...	...
Removed from list	...	...	...	...	− 8	...	...
1934 December 31	1	4	1	217	669	45	937

(Six Associates are also Fellows, and are therefore counted twice in the above table.)

RECEIVED

	£ s. d.	£ s. d.
Balances, 1934 January 1 :—		
In hand of Assistant Secretary on Petty Cash Account	9 10 10	
At Bankers', on Current Account	464 17 0	
At Bankers', on "C" Account (Trust Funds) (including balance of Potter Bequest, £17, 15*s.* 2*d.*)	115 4 1	
		589 11 11
Received on account of Dividends :—		
£1250 Metropolitan Consolidated 3% Stock	37 10 0	
£2000 Swansea Corporation 3½% Stock	70 0 0	
£2287, 6*s.* 9*d.* East Indian Railway 3% Debenture Stock	52 14 9	
£5125 London, Midland and Scottish Railway 4% Debenture Stock	156 6 3	
£750 London, Midland and Scottish Railway 4% Consolidated Preference Stock	22 15 7	
£2400 Gas Light & Coke Co. 3% Debenture Stock	54 18 0	
£2000 Commercial Gas Co. 3% Debenture Stock	46 10 0	
£1035 Agricultural Mortgage Corporation 4½% Debenture Stock, 1961–91	36 2 0	
£695, 16*s.* Conversion Loan 3½% Stock, 1961	24 7 0	
£419, 17*s.* 11*d.* Conversion Loan 4½% Stock, 1940–44	18 17 10	
£700 Birmingham Corporation 3% Inscribed Stock, 1947	21 0 0	
£496 Consolidated Loan 4%	19 16 8	
£2000 New Zealand 3½% Loan, 1940	70 0 0	
£1000 Hull Corporation 4½% Redeemable Stock, 1957–72	45 0 0	
£800 War Loan 3½% Inscribed Stock	28 0 0	
£500 New South Wales 4% Stock, 1942–62	15 5 0	
£1000 Central Electricity Board 4½% Stock, 1957–82	34 6 3	
Income Tax refunded, 1933 April–1934 April	135 17 5	
	889 6 9	
Sales of Publications £303 2 10		
Reprints (including £37, 2*s.* 0*d.* due 1933) 98 8 5		
	401 11 3	
Sales of Photographs	83 3 6	
Miscellaneous Receipts :—		
London Mathematical Society, expenses of Meetings, etc. £30 0 0		
Assistant Secretary and Clerk, Pension Premiums ... 19 5 0		
Postages repaid 5 15 3		
Use of Telephone 0 15 3		
Sale of Waste Paper 0 17 6		
	56 13 0	
		1430 14 6
Received on account of Subscriptions :—		
571 Annual Contributions for 1934 (including 3 Institutional Membership fees)	1199 2 0	
1 Part Contribution for 1934 (on account)	13 0	
16½ Annual Contributions for 1935 in advance (including 1 Institutional Membership fee)	34 13 0	
25 Admission Fees	52 10 0	
23 First Contributions at 2 guineas	48 6 0	
2 First Contributions at 1 guinea	2 2 0	
Arrears paid off :—		
13 for 1932 ... ... £27 6 0		
53½ for 1933 ... ... 112 7 0		
	139 13 0	
		1476 19 0
Compositions (reduced)		11 11 0
Trust Fund Dividends :—		
£1212, 13*s.* 3*d.* East Indian Railway 3% Debenture Stock	27 19 6	
£542, 18*s.* 2*d.* India 3½% Stock	19 0 0	
£965 Agricultural Mortgage Corporation 4½% Debenture Stock, 1961–91	33 13 2	
£1004 Consolidated Loan 4%	40 3 2	
Donation from General Fund (balance of George Darwin Lecture fee)	9 16 10	
Income Tax refunded, 1933 April–1934 April	19 18 8	
		150 11 4
		£3659 7 9

Examined and found correct.
(Signed) D. H. SADLER.
J. C. P. MILLER.

1935 *January* 15.

ASTRONOMICAL SOCIETY, FROM 1934 JANUARY 1 TO DECEMBER 31

Account

PAID

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
Clerk: Salary	175	0	0			
Assistant Secretary and Clerk, for work done for London Mathematical Society in 1933	10	0	0			
Pension Premiums, Assistant Secretary and Clerk	57	15	0			
Porter and Wife: Wages	154	1	6			
Health and Unemployment Insurance	6	18	8			
				653	15	2
Licence for Porter	0	15	0			
Fire and Accident Insurance	14	1	0			
Telephone	12	19	10			
Telegraphic Address	2	0	0			
Time Signal	5	2	8			
Water Rate	12	12	0			
				47	10	6
Postage and Packing:—						
Monthly Notices, etc.,	117	12	3			
Office Postages	54	17	1			
				172	9	4
Printing, etc.:—						
Monthly Notices (Vol. **94**, Nos. 1–9)	997	9	9			
Geophysical Supplements (Vol. **3**, Nos. 5, 6)	71	10	1			
General Index to *Monthly Notices*, Vols. **71-91**	147	16	8			
Reprints	117	8	10			
Miscellaneous	74	17	3			
Photo-engraving:—						
Monthly Notices £60 7 7						
Geophysical Supplements 2 6 6						
	62	14	1			
				1471	16	8
Reproduction of Photographs for sale				88	10	5
Stationery and Office Expenses	28	8	1			
Library Equipment, Binding, Purchase of Books (General Fund)	39	8	1			
Purchase of Books (Potter Fund)	22	19	0			
Reproduction of Presidents' Portraits	13	4	3			
Reproduction of Early Parts of *Monthly Notices* by "Replika" Process	11	19	6			
Subscription to International Telegrams Bureau	2	14	10			
Subscription to Committee on Library Co-operation	1	1	0			
Subscription to Lamont Memorial	5	0	0			
Easy Chairs for Library	14	10	0			
Heating and Lighting	125	7	6			
Fittings and Repairs	28	12	2			
House Expenses and Laundry	24	1	5			
Authorised Travelling Expenses	10	12	6			
Balance of George Darwin Lecture Fee	9	16	10			
Expenses of R.A.S. Meetings	17	3	0			
Expenses of Geophysical Meetings	6	13	8			
Expenses of L.M.S. Meetings	5	16	3			
Address to University of Catania	1	19	6			
Miscellaneous Expenditure	12	13	1			
Bank Charges and Cheque Books	2	14	8			
				384	15	4
				2818	17	5
Expenditure on Trust Accounts:—						
George Darwin Lecture Fee	50	0	0			
Turnor and Horrocks Fund (Library)	18	16	8			
Harry Watson Fund (Library)	67	6	5			
				136	3	1
Balances, 1934 December 31:—						
In hand of Assistant Secretary on Petty Cash Account	4	9	10			
At Bankers', on Current Account (including balance of Potter Fund, £5, 6*s.* 2*d.*)	581	14	3			
Cheque not yet credited	6	6	0			
At Bankers', on "C" Account (Trust Funds)	111	17	2			
				704	7	3
				£3659	7	9

Revenue

	£	s.	d.	£	s.	d.
To General Expenditure as per Cash Account	2818	17	5			
,, Reserve for Accounts due but not presented...	145	0	0			
	2963	17	5			
Less Reserve for Accounts due 1933 now written back ...	240	0	0			
				2723	17	5
,, Amount transferred to Composition Fees Reserve Fund in 1934...				11	11	0
,, 17 Annual Contributions in Arrear written off	35	14	0			
,, 10 Annual Contributions 1934 written off as per contra ...	21	0	0			
				56	14	0
,, Excess of Income over Expenditure, 1934				161	1	3
				£2953	3	8

Examined and found correct.

(Signed) D. H. SADLER.
J. C. P. MILLER.

1935 *January* 18.

Account, 1934

		£	s.	d.	£	s.	d.
By Subscriptions—							
571	Annual Contributions 1934, including 3 Institutional Membership Fees	1199	2	0			
1	Part Contribution for 1934 (on account)		13	0			
29	ditto paid 1931, 1932 and 1933, now matured	60	18	0			
59	ditto, outstanding (*less* 13*s.*)	123	5	0			
10	Contributions for 1934 due, but unpaid, in respect of Fellows died, resigned, or names removed, and written off per contra	21	0	0			
					1404	18	0
,, 23	First Contributions, 1934, at 2 guineas	48	6	0			
,, 2	ditto, at 1 guinea	2	2	0			
25					50	8	0
,, 25	Admission Fees, 1934				52	10	0
,, 2	Composition Fees (reduced)				11	11	0
,,	6% of Composition Fees Reserve Fund as per Balance Sheet, transferred to Current Revenue				38	3	1
,,	Sundry Debtors, 1934				19	19	11
,,	Dividends, Sales of Publications and Photographs, and Miscellaneous Receipts, as per Cash Account	1430	14	6			
Less	Payments due in 1932 £0 11 10; Payments due in 1933 (£40, 7*s.* 0*d.*, *less* 19*s.* still outstanding) 39 8 0; Advance payments for *Monthly Notices*, Vol. 95 52 5 3; Income Tax (General Fund) 1933 April–December, refunded in 1934 84 2 10	176	7	11			
					1254	6	7
,,	Payments for *Monthly Notices*, Vol. **94**, received in 1933 and now matured				43	17	9
,,	Credits for Overpayments on Publications in 1931, now liquidated				0	17	11
,,	Income Tax (General Fund) deducted at source 1934 April–December, not yet refunded				76	11	5
					£2953	3	8

Balance Sheet

LIABILITIES

	£ s. d.	£ s. d.
1 Subscription for 1935, paid in 1931	2 2 0	
16½ Subscriptions for 1935, paid in 1934	34 13 0	
		36 15 0
Sundry Creditors for Accounts due but not presented ...		145 0 0
Cash Balances (Income) of Trust Funds—		
Turnor and Horrocks Fund	3 12 2	
Harry Watson Fund	3 19 9	
Lee and Janson Fund	36 15 3	
Hannah Jackson Fund	47 8 5	
George Darwin Lectureship Fund	20 1 7	
		111 17 2
Trust Funds (Capital), as per contra		2964 0 0
Income Tax on Trust Funds, 1934 April–December, not yet refunded, as per contra		15 18 1
Special Fund (Capital), as per contra		1460 0 0
Composition Fees Reserve Fund—		
As at 1933 December 31	624 4 9	
Received in 1934	11 11 0	
	635 15 9	
Less 6% transferred to current revenue	38 3 1	
		597 12 8
Advance payments for *Monthly Notices*, Vol. 95		52 5 3
Credit for overpayment on publications, 1932		0 11 0
General Fund—		
As at 1933 December 31	17,343 18 9	
Add Excess of Income, over Expenditure, 1934... ...	161 1 3	
		17,505 0 0
		£22,888 19 2

Examined and found correct.

(Signed) D. H. SADLER.
J. C. P. MILLER.

1935 *January* 18.

1934 *December* 31

ASSETS

	£ s. d.	£ s. d.
Sundry Debtors for Subscriptions in Arrears—		
14½ for 1933	30 9 0	
59 for 1934 (*less* 13*s.*)...	123 5 0	
		153 14 0
Sundry Debtors, 1933		0 19 0
Sundry Debtors, 1934 :—		
Due for Publications and Reprints	15 7 10	
Due for Photographs	2 0 0	
Due for Postages	2 12 1	
		19 19 11
Investments of General Fund, valued as in 1933 Balance Sheet		17,493 9 6
Investments of Special Fund, valued at cost		1460 0 0
Investments of Trust Funds, valued as in 1933 Balance Sheet		2964 0 0
Income Tax 1934 April–December, deducted at source and not yet refunded—		
General Fund	76 11 5	
Trust Funds	15 18 1	
		92 9 6
Sundry Balances—		
In hand of Assistant Secretary on Petty Cash Account ...	4 9 10	
At Bankers', on Current Account (including cash balance of Potter Fund, £5, 6*s.* 2*d.*)	581 14 3	
Cheque not yet credited	6 6 0	
At Bankers', on " C " Account (Trust Funds)	111 17 2	
		704 7 3
		£22,888 19 2

Astronomical and other Manuscripts, Books, Prints, Photographs and Instruments.
Furniture, etc.
Stock of Publications and Photographs for sale.
One Gold Medal.
Four Bronze (Jackson-Gwilt) Medals.
} Not valued.

The Stock Exchange Valuation of the Investments on 1934 December 20 was £28,700 as compared with £21,917, 9*s.* 6*d.*, the value shown above.

J. H. R.

INVESTMENTS

As at 1934 December 31

General Fund

£1250 Metropolitan Consolidated 3-per-cent. Stock, 1941.
£2000 Swansea Corporation 3½-per-cent. Stock.
£2287, 6*s.* 9*d.* East Indian Railway 3-per-cent. New Debenture Stock.*
£5125 London, Midland and Scottish Railway 4-per-cent. Debenture Stock.*
£750 London, Midland and Scottish Railway 4-per-cent. Preference Stock.*
£2400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.*
£2000 Commercial Gas Co. 3-per-cent. Consolidated Debenture Stock.*
£496 Consolidated 4-per-cent. Loan, 1967.
£500 Agricultural Mortgage Corporation, Ltd., 4½-per-cent. Debenture Stock, 1961–91.*
£1000 Hull Corporation 4½-per-cent. Redeemable Stock, 1952–72.
£1000 Central Electricity Board 4½-per-cent. Stock, 1957–82.*
£2000 New Zealand 3½-per-cent. Loan, 1940.
£700 Birmingham Corporation 3-per-cent. Inscribed Stock, 1947.
£800 War Loan 3½-per-cent. Inscribed Stock.
£500 New South Wales 4-per-cent. Stock, 1942–62.*

Grove-Hills Special Fund

£419, 17*s.* 11*d.* Conversion Loan 4½-per-cent., 1940–44.
£695, 16*s.* 0*d.* Conversion Loan 3½-per-cent., 1961.
£535 Agricultural Mortgage Corporation, Ltd., 4½-per-cent. Debenture Stock, 1961–91.*

Five Trust Funds

£1212, 13*s.* 3*d.* East Indian Railway 3-per-cent. New Debenture Stock.*
£542, 18*s.* 2*d.* India 3½-per-cent. Stock.
£1004 Consolidated 4-per-cent. Loan, 1967.
£965 Agricultural Mortgage Corporation, Ltd., 4½-per-cent. Debenture Stock, 1961–91.*

* Taxed at source.

REPORT OF THE AUDITORS FOR THE YEAR 1934

We have examined the Treasurer's account of receipts and expenditure, the Revenue Account and the Balance Sheet for the year 1934, and have certified them to be correct. The investment holdings have been certified either by the Bank of England or by the Westminster Bank, and are in accordance with the printed list. The Stock Exchange valuation of the investments on 1934 December 20 shows an increase of nearly 31 per cent. over the value given in the Balance Sheet.

The number of annual subscribers shown in the Table of Progress and Present State of the Society has been rigorously checked against the subscriptions shown in the Revenue Account, and this has led to the discovery that two resignations were omitted from the 1933 table; these have been included in the 1934 table.

The excess of income over expenditure as shown by the Revenue Account is £161. This compares unfavourably with the corresponding figure for last year, but the decrease is largely attributable to the following differences. First, no application was made to the Royal Society for a repetition of last year's grant of £50 towards the cost of printing the *Geophysical Supplements*. Secondly, a General Index to *Monthly Notices* (71–91) has been printed at a cost of approximately £150, and although this expenditure is almost balanced in last year's accounts by the production of a List of Fellows and of *Memoirs* (65, Part 2), the expense of the latter was defrayed by a donation from the University of Michigan. Thirdly, the Council have resumed the policy of supplying a limited number of free reprints.

The sum held in reserve in respect of the liability to Fellows who have compounded is now £597, 12*s*. 8*d*., a decrease of £27, this being accounted for by the abnormally low receipts for Composition fees in 1934.

Advantage has been taken of the Archdeacon Potter Bequest to purchase several valuable and interesting old books, including a first edition of one of Galileo's most important works. An interesting and unique collection of sixteenth century tracts on Comets and Novæ has also been purchased out of the Harry Watson Fund. One of the books reported as missing in the Auditors' Report for 1929, namely *Archimedis quæ supersunt omnia*, has now been found.

Mrs. Tomkins has presented to the Society the large collection of Moon negatives made by the late Mr. H. G. Tomkins. This will form a valuable addition to the Society's property.

A list has been laid on the table containing the names of those Fellows who are still in arrear for sums due on 1934 January 1, with the amount due against each Fellow's name.

We have inspected the Society's premises and have found everything in

satisfactory condition. It is suggested, however, that advantage might be taken of recent bequests to rebind some of the older books that are in need of repair. We note that the much faded portraits of past Presidents have been reproduced by a new process and that the reproduced portraits now hang in the meeting room; we also note that encouragement has been given to users of the Library by the purchase of two easy chairs.

We have received from the Assistant Secretary all the information and explanations we have required in the elucidation and certification of the accounts.

(Signed) D. H. Sadler.
J. C. P. Miller.

1935 *January* 24

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY

The John Lee Gift: In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Parsons Gift (1922): The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock 1929–47, in memory of his father, the 3rd Earl of Rosse, who made the 6-foot reflector, and who died 1867 October 31.

The Grove-Hills Bequest (1922): Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early astronomical and mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Lindemann Bequest (1931): A. F. Lindemann, Esq., bequeathed to the Society the sum of £1000, free of legacy duty.

The Archdeacon Potter Bequest (1933): Archdeacon Beresford Potter bequeathed to the Society a 3/88th share of his residuary estate, amounting to £318, 16*s.* 2*d.*

THE GROVE-HILLS SPECIAL FUND

In 1923 the Treasurer, Col. Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. The total amount received from all sources (including dividends on the investments representing the fund) has been £1913, 1*s.* 11*d.*, of which £1480, 2*s.* 10*d.* has been invested and is now represented by £535 Agricultural Mortgage 4½ per cent., £419, 17*s.* 11*d.* Conversion Loan 4½ per cent. 1940–44, and £695, 16*s.* Conversion Loan 3½ per cent. 1961.

THE ARCHDEACON POTTER FUND

The late Archdeacon Beresford Potter, who died 1931 May 10, bequeathed to the Society a 3/88th share of his residuary estate. This legacy was received in 1933, and now stands invested in £300 3½ per cent. War Stock, the cash balance of £17, 15*s.* 2*d.* being expended on the library in 1934. The Council resolved to allocate the dividends from this Fund for the purposes of the library.

	£	*s.*	*d.*
1934 Jan. 1. Balance of Fund	17	15	2
1934. Dividends, War Stock 3½ per cent.	10	10	0
	£28	5	2

	£	*s.*	*d.*
1934. Purchase of Books ...	22	19	0
1934 Dec. 31. Balance of Fund	5	6	2
	£28	5	2

TRUST FUNDS

The Lee and Janson Fund : In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1934 Jan. 1. Balance of Fund	26	10	10	1934 Dec. 31. Balance of Fund	36	15	3
1934. Dividends, East Indian Railway ...	7	14	5				
Income Tax, 1933 April–1934 April, refunded ...	2	10	0				
	£36	15	3		£36	15	3

The Turnor Fund and the Horrocks Memorial Fund : In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks : to this the Society added the sum of £55, 15*s.*, and the whole now stands in £103, 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the library.

	£	*s.*	*d.*		£	*s.*	*d.*
1934 Jan. 1. Balance of Fund	5	1	4	1934. Purchase of Books ...	18	16	8
1934. Dividends, East Indian Railway ...	13	2	2	1934 Dec. 31. Balance of Fund	3	12	2
Income Tax, 1933 April–1934 April, refunded ...	4	5	4				
	£22	8	10		£22	8	10

The Harry Watson Memorial Fund : In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* India 3½-per-cent. stock. In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s.* to the Society, which now stands invested in £965 Agricultural Mortgage 4½-per-cent. Stock. The Council resolved that these two sums should together constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books.

	£	s.	d.		£	s.	d.
1934 Jan. 1. Balance of Fund	7	16	0	1934 Purchase of Books ...	55	10	8
1934. Dividends, India 3½ per cent.	19	0	0	Binding	11	15	9
Dividends, Agricultural Mortgage 4½ per cent.	33	13	2	1934 Dec. 31. Balance of Fund	3	19	9
Income Tax, 1933 April–1934 April, refunded	10	17	0				
	£71	6	2		£71	6	2

The Hannah Jackson (née Gwilt) Fund : In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock ; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	s.	d.		£	s.	d.
1934 Jan. 1. Balance of Fund	37	19	2	1934 Dec. 31. Balance of Fund	47	8	5
1934. Dividends, East Indian Railway ...	7	2	11				
Income Tax 1933 April–1934 April, refunded ...	2	6	4				
	£47	8	5		£47	8	5

The George Darwin Lectureship Fund : In 1926 June Sir James Jeans presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George Darwin Lectureship*, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

This sum now stands in £1004 Consolidated 4-per-cent. Loan. The income is annually applied to the purposes of the Trust in accordance with the terms of the Deed of Gift.

	£	s.	d.		£	s.	d.
1934 Jan. 1. Balance of Fund	20	1	7	1934 May. Lecture Fee ...	50	0	0
Dividends, Consolidated 4 per cent. Loan	40	3	2	1934 Dec. 31. Balance of Fund	20	1	7
Donation from General Fund	9	16	10				
	£70	1	7		£70	1	7

CELESTIAL PHOTOGRAPHS

The following have been added to the list of Celestial Photographs reproduced by the Society for sale to Fellows :—

R.A.S. Ref. No.

J 91. Group of Spiral Nebulæ in Pegasus (N.G.C. 7317–20). Mount Wilson Observatory. 1916 Aug. 26, 27. 60-inch Reflector. Exp. 7 h. 45 m.

I 39. Pelican Nebula in Cygnus. M. de Kerolyr, Forcalquier. 1932 Nov. 80 cm. (32-inch) Reflector. Exp. 8 h. 15 m.

I 40. N. America Nebula (N.W. end). M. de Kerolyr, Forcalquier. 1933 Aug. 80 cm. (32-inch) Reflector. Exp. 18 h.

I 41. N.G.C. 2023–24 (following ζ Orionis). M. de Kerolyr, Forcalquier. 1934 Feb. 80 cm. (32-inch) Reflector. Exp. 11 h.

J 92. Andromeda Nebula (N. end). M. de Kerolyr, Forcalquier. 1933 Dec. 80 cm. (32-inch) Reflector. Exp. 8 h. 30 m.

I 42. Nebula I.C. 405. M. de Kerolyr, Forcalquier. 1933 Jan. 18, 20, 21. 80 cm. (32-inch) Reflector. Exp. 13 h.

I 43. Nebula near N.G.C. 6960 (Cygnus). M. de Kerolyr, Forcalquier. 1933 Oct. 10–15. 80 cm. (32-inch) Reflector. Exp. 14 h.

I 44. Nebula N.G.C. 1977. M. de Kerolyr, Forcalquier. 1934 Jan. 10. 80 cm. (32-inch) Reflector. Exp. 3 h.

I 45. Nebula in the Pleiades. M. de Kerolyr, Forcalquier. 1932 Nov. 3, 4. 80 cm. (32-inch) Reflector. Exp. 6 h.

J 93. Nebula N.G.C. 3623, 3627 (M 65, M 66). M. de Kerolyr, Forcalquier. 1934 April 9. 80 cm. (32-inch) Reflector. Exp. 2 h. 15 m.

J 94. Nebula N.G.C. 5055 (M 63). M. de Kerolyr, Forcalquier. 1934 April. 80 cm. (32-inch) Reflector. Exp. 2 h. 45 m.

I 46. Nebula I.C. 5146 (Cygnus). M. de Kerolyr, Forcalquier. 1933 Aug. 20–22. 80 cm. (32-inch) Reflector. Exp. 12 h. 30 m.

K 7. Cluster N.G.C. 5904 (M 5). M. de Kerolyr, Forcalquier. 1934 May 18. 80 cm. (32-inch) Reflector. Exp. 2 h.

I 47. Nebula in Belt of Orion. M. de Kerolyr, Forcalquier. 1929 Jan. 4·8-inch. lens, *f.l.* 48 inches. Exp. 12 h.

R 3. Infra-red Spectrum of Iron Arc. λ 8838–λ 10219A. Dingle, S. Kensington. 1934. (See *M.N.*, 94, 866, 1934.)

PUBLICATIONS OF THE SOCIETY

During the past year the Society has published *Monthly Notices*, vol. 94 ; *Geophysical Supplements*, vol. 3, Nos. 5, 6 ; and *General Index to Monthly Notices Vols. 71–91.*

OBITUARY

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Henry Osmund Barnard
Joseph Bevan Braithwaite
Arthur Neville Brown
Thomas H. E. C. Espin
Edward Osborne Fountain
Gerald Edward Galbraith
*Edmund Goetz
Sir Horace Lamb
*William Ralph Mechaelis
Maria Victoria Vicenta de Rivas
John Archibald Rupert-Jones
Sir Arthur Schuster
Duncan McLaren Young Sommerville
Walter Edward Stewart
William Morgan Tate-Stoate
Herbert Gerard Tomkins
George Vickars-Gaskell
Michael Heriot Huth Walters
Edward Fawcett White

Associates :—Benjamin Baillaud
Julius Bauschinger
Aristarch Belopolsky
Carl Vilhelm Ludvig Charlier
Willem de Sitter

JOSEPH BEVAN BRAITHWAITE was born in Camden Town on 1855 October 5. His father was a well-known member of the Society of Friends, and Braithwaite received his education at the Friends' School at Kendal and later at Grove House School, Tottenham. His father entered him for the Middle Temple, but he had little taste for law, and sixty years ago he entered his uncle's office. This uncle was Isaac Braithwaite, then senior partner in a firm of stock and share brokers. Braithwaite became a partner in 1880 and retired in 1922. In the business world he will be remembered as one of the first to see the possibilities of the electrical industry when in its infancy nearly fifty years ago. He was instrumental in raising capital to float several electric lighting companies. He was deeply interested in religious work.

In 1881 he married Anna Sophia Gillett, by whom he had one daughter

* Died 1933. Death not notified till 1934.

and five sons, one of whom is the present member of Parliament for the Hillsborough Division of Sheffield. She died in 1899. In 1901 he married Grace Moscrip who survives him. There are no children of the second marriage.

He died on 1934 November 30.

He was elected a Fellow of the Society on 1930 February 14.

ARTHUR NEVILLE BROWN was born on 1864 June 18 at Nayland in Suffolk, the eldest son of the Rev. J. T. Brown. He was educated at St. Edmund's School, Canterbury, and Queen's College, Oxford. A classical scholar, he went as First Classical Master to Canon Lovett Cameron's Preparatory School at Mortimer until 1898, when he was appointed Assistant Master at Ludgrove, of which well-known preparatory school he later became co-Headmaster, retiring in 1923 after a most successful scholastic career. He died on 1934 November 4 at Brackenhurst, Bucklebury Common, Berks, where he had lived since his retirement, keenly interested in his garden as well as his astronomical pursuits.

Although his general interest in astronomy appears to have dated from at latest 1891, he did not become an active observer until 1905, when he acquired the 5-inch Watson-Conrady refractor on altazimuth tripod stand which he was to use, and to the last always in the open, until only a few days before his short final illness. With this instrument, and a 3-inch added soon afterwards, was begun a twenty-seven and a half years' series of Variable Star Observations which, for continuity and the care that went to its making, can have but few equals among those recorded by amateur astronomers. Most of these observations (and there are well over 40,000 of them) were discussed and published in the *Journal* and *Memoirs* of the British Astronomical Association as part, and a very essential part, of the work of its Variable Star Section. These observations will be found in *M.B.A.A.*, 18, 22, 25, 28 and 31. Observations of four long-period Variables were communicated to the Society in seventeen papers (an interesting analysis of three of these series was made by Miss Blagg and published in *M.N.*, **89**, 687; **90**, 552; and **91**, 231). Observations of several further stars were sent regularly to the American Association of Variable Star Observers.

It was, however, not only at the telescope that he was active in the interests of astronomy. Almost from the beginning and in ever-increasing measure he helped three successive Directors of the V.S.S., B.A.A., in the very heavy clerical work involved both in the compilation of the *Memoirs* above mentioned and in the routine work of the Section, of which he became Secretary in 1924.

In this connection it is interesting to note that, although the more scientific side of the subject did not engage much of his attention, once assured by competent authority that, as material for future investigators, the work was worth doing, he shirked no drudgery that in his opinion might be necessary to eliminate avoidable errors. Thus observers whose work passed through his hands for publication could feel confident that every care was being taken to present their results with all possible accuracy. To

this quality in him Variable Star Astronomy owes a great debt both practically and as an example. The same quality pervaded his large correspondence with Variable Star observers who were always assured of a remarkably fresh, lively and sympathetic interest in their problems, so much so that many who never even met him personally have felt his death as the loss of a real friend. Modest and retiring by nature, it may be said that on the whole he attended astronomical meetings only when he felt that it was in the interests of his particular work, anything over and above this being regarded as an interruption of observing and compiling routine. He was also joint author with M. Felix de Roy of a valuable pamphlet on "The Observation of Variable Stars," which was published in *J.B.A.A.*, **33**, 143, 1923. If, lastly, we add that financially too he was most generous towards the work of the V.S.S., B.A.A., no further words are needed to express the debt owed to him by that body and, more generally, by this branch of Astronomy.

He served on the Council of the B.A.A., having become a Life Member of the Association on 1905 November 29, and had been a member of the Variable Star Commission of the I.A.U. since 1925. He represented the B.A.A. on the National Committee for Astronomy from 1931 until his death.

He was elected a Fellow of the Society on 1907 April 12.

W. M. L.

THOMAS HENRY ESPINALL COMPTON ESPIN was born at Birmingham on 1858 May 28. He was the only child of the Rev. Thomas Espin, D.D., D.C.L., Chancellor of the Diocese of Chester. He was a descendant of the great Canonist van Espen, Professor at the University of Louvain.

From 1872–1876 he was at Haileybury, and while there his interest in astronomy was aroused by the appearance of Coggia's comet in 1874 and by some weekly talks by his form master. He was not, however, particularly successful at school, and used to say that his only prize was for good conduct. At Exeter College, Oxford, which he entered in 1878, he studied theology and gained second-class honours, but was informed that he would have had a "first" had he taken the Hebrew paper. While at Oxford his interest in astronomy steadily developed, and the Savilian Professor, the Rev. C. Pritchard, allowed him the use of the 13-inch De la Rue telescope on the condition of his assisting the students in their practical telescopic work. He was elected a Fellow of the Society on 1878 January 11, during the presidency of Sir William Huggins, and was accordingly one of our oldest Fellows.

After leaving Oxford he took Holy Orders and became Curate successively at West Kirby in 1881, at Wallasey in 1883, and two years later at Wolsingham. In 1888 he was appointed Vicar of Tow Law, and held the living till the time of his death—a period of forty-six years.

In the early days of his astronomical career Espin used small- or moderate-sized instruments. He began at school with a telescope of 1-inch aperture by Dollond, and found his first double star with a 3-inch. Later he was presented with a 5-inch refractor by the head of the Harrison line of steamers,

who was a Churchwarden at Wallasey, and in 1885 a legacy from the Rev. T. W. Webb helped him to purchase a $17\frac{1}{4}$-inch Calver reflector. This was followed in 1914 by a 24-inch reflector, also by Calver, and from that date the $17\frac{1}{4}$-inch has been assiduously used by his pupil and assistant, Mr. W. Milburn.

Espin's astronomical work may be roughly divided into two parts, viz. that comprised within the period 1885–1899, and that from 1900 to the end of his career. In the former his main interest lay in the search for red stars, and this led him to undertake a general spectroscopic survey in the course of which he made many important discoveries. These included several variable stars, about 400 stars of Secchi's type III and 50 of type IV. He communicated a catalogue of stars of this latter class, including those discovered by himself and those previously known, to the Society in 1898 (*M.N.*, **58**, 443). He also devoted much attention to the visual spectra of nebulæ, and found several objects of this class.

In 1890 he published a new edition of Birmingham's *Catalogue of Red Stars*, incorporating the discoveries by himself and others. His lists of "Stars with Peculiar Spectra," communicated to the *Astronomische Nachrichten* each year from 1887 to 1896, comprised no less than 1180 objects. His own MS. Catalogue of 3800 Red Stars found by him between 1885 and 1899 was eventually included in Krüger's *Neuer Katalog Farbiger Sterne* and published as vol. vii of *Specola Astronomica Vaticana*. Later, in a paper to the Society (*M.N.*, **85**, 98), he compared his visually observed spectroscopic results with the photographic classification of the Draper Catalogue, and found that of every 100 stars in his list 68 are of K type, 24 of M type, 6 of G or F and 2 of N.

But although after 1899 the main direction of his astronomical work was changed he always retained his interest in the objects of his earlier researches, and continued to publish papers giving details of red stars, stellar spectra, etc., which he noted in the course of his search for double stars. It was under the title "Note on the Visual Spectrum of an Uncatalogued Red Star in Lacerta" that he communicated to the Society the account of his discovery of Nova Lacertæ on 1910 December 30 (*M.N.*, **71**, 189). For this discovery and his general observations of the spectra of stars he was awarded the Society's Jackson-Gwilt Medal and Gift in 1913.

In the year 1900 Espin turned his attention to the study of double stars with his $17\frac{1}{4}$-inch reflecting telescope, and from that time onward this department of work was followed up with the same keenness and assiduity as had marked his search for red stars and his observations in stellar spectroscopy. He was the first and only observer since the days of Sir John Herschel to embark on and carry through an extensive double-star programme with a reflector, but it is to be noted that the nature of his work was of the kind for which his instrument was adequate. He made no attempt to measure very close pairs demanding steady images and critical definition under high magnification—conditions not so readily obtainable with reflecting telescopes as with refractors—but devoted himself to the search for comparatively wide pairs. Actually his programme consisted in the

examination of B.D. stars, and every year he published in *Monthly Notices* lists of the pairs found as well as measures of Struve and other doubles already known. His last list (*M.N.*, **93**, 192) contained the reference number 2575—the number of his own discoveries. Though, probably in consequence of his distance from London, he took no part in the activities of the British Astronomical Association, he was nevertheless interested in amateur work in general. He was a founder, and had been President, of the Liverpool Astronomical Society, and was the first President of the Newcastle Astronomical Society, holding this office till the end of his life. He was made a corresponding Fellow of the R.A.S. of Canada in 1893, Honorary Fellow of the Astronomical Society of Mexico in 1911, and Fellow of the Astronomical and Astrophysical Society of America in 1914. He had been a member of the Double Star Commission of the International Astronomical Union since its inception.

Among his publications not already referred to may be mentioned the *Wolsingham Observatory Circulars*, new editions of Proctor's large and small Star Atlases, and the 5th and 6th editions of Webb's *Celestial Objects for Common Telescopes*—the latter work being now extended to two volumes.

Espin had, of course, a large circle of friends and correspondents among astronomers, including Webb, Huggins, Common, E. C. Pickering and Burnham. He also remembered being taken as a child to see Sir John Herschel. He became acquainted with Webb in 1876, and assisted him with some of the earlier editions of his *Celestial Objects*. He used to say that Webb could see planetary detail which he could not see, but that he could detect faint satellites and *comites* of stars which were invisible to Webb. Burnham in some of his letters expressed surprise that he was able to detect stars which he himself found not easy even with the great refractor of the Yerkes Observatory. In addition to his exceptionally keen sight, he possessed also great powers of endurance. He was known on occasions to continue at work for as long as thirteen hours without a break, and his usual hours of observation were from sunset to 3.0 or 3.30 the following morning.

But Espin had other interests and pursuits besides astronomy, and into some of them he had gone deeply. He was a keen microscopist, and, following the announcement of Röntgen's discovery, became a pioneer in the construction of X-rays apparatus, which he often used for the benefit of patients. As a botanist he was particularly interested in mosses, and as a geologist he made a special study of fossils and rocks—particularly those of volcanic character from Vesuvius, Etna and Puy de Dôme, and frequently went abroad to collect specimens. He himself made over 500 fine rock sections. In 1923 he spent a week on Vesuvius, where he was once overcome by sulphurous fumes while his assistant was taking photographs inside the crater. Of late years he had investigated local springs for evidences of radio-activity, and met with some success. It should be mentioned that his geological studies of fossils led him to disbelieve in the Darwinian theory of the evolution of life. In his early days he had been taught music by Sir Walter Parratt, and at Oxford he became a friend of Spinney. He was

a keen pianist, and for many years was his own organist at Tow Law Church, where the musical settings for the Choral Eucharist were his own compositions.

As Vicar of Tow Law he gained and held the high regard and affection of all, as was shown on the occasion of his funeral service. He disliked party labels and controversy, and his natural independence of character showed itself in his refusal to have a Parochial Church Council. But he abounded in human sympathy as was indicated by all he did for his parishioners—both the sick and the whole. The use of his X-rays apparatus has already been mentioned, and he built a sanatorium for cases of tuberculosis. One of the first things he did on being appointed Vicar was to lay down a hard tennis court for the use of the parishioners. He also built a miniature rifle range and gymnasium, and his vicarage was always an open house for members of the Church Lads' Brigade, scouts, choristers and others. Perhaps his particular interest was in the lads and young men of the parish, several of whom he instructed in Latin, Greek and French. Of these some now hold important posts, including five who are in orders in the Church of England.

In 1891 he was appointed a County Magistrate, and became Chairman of Stanhope and Wolsingham Sessions. In 1933 he was put on the Appeal Committee of the County.

As regards his personal characteristics Espin was most friendly and hospitable, and possessed a very keen sense of humour. He never married, and had few surviving relatives. The writer of this notice is indebted for much of the information it contains to his pupil, assistant and close companion, Mr. Milburn.

Espin died on 1934 December 2 after a comparatively short illness, though he had been gradually failing for some time. He had lived for science and for his people. All who knew him will remember him as a great man, an enthusiastic student of Nature and a true friend.

T. E. R. P.

EDWARD OSBORNE FOUNTAIN was born at West Drayton in 1857. He was educated at Marlborough, whence he went to Pembroke College, Cambridge. He took the Mathematical Tripos, being placed as seventh wrangler, and he then entered St. Bartholomew's Hospital as a medical student. In due course he qualified and subsequently entered upon medical practice.

Fountain was a keen amateur astronomer. His astronomical activities were mainly divided between the observation of the Lunar Surface and the study of dynamical astronomy and of cosmogony. He was elected a Fellow of the Society on 1921 June 10. In the same year he proposed an ingenious way of solving directly, with the aid of addition and subtraction logarithms, the cubic equation in $\tan \frac{1}{2} v$ that occurs in the process of finding the true anomaly in a parabolic orbit. This paper was one of many by Fountain that appeared at various times in the *Journal of the British Astronomical Association*. It drew from Merfield the comment that the hyperbolic sine could also be

used for a direct solution, whereupon Fountain showed that all cubics could be solved directly by circular or hyperbolic functions.

In 1913 Fountain had retired from medical practice. He and his wife then settled at Ruislip, near Uxbridge in Middlesex. Archæology was one of his hobbies. He became a keen student of the history of the district and was strong in his advocacy of preserving things associated with the past. He was a popular figure in Ruislip and the news of his death on 1934 November 25 was received there with great regret, as also by his astronomical friends and acquaintances. In particular the members of the British Astronomical Association mourn the loss of a former treasurer and a zealous member.

MAJOR GERALD EDWARD GALBRAITH was born at Portsmouth on 1862 December 5, and was the only son of Dr. G. T. Galbraith of the Army Medical Service. He was educated at Stanley House School, Bridge of Allan, and at Epsom College. He entered the Army and saw active service with the R.G.A. in the Burmese War, the Boxer Rising, and the South African War. He also served in India, and during the Great War of 1914–18 he commanded a fort near Plymouth. On his retirement he devoted himself to scientific study. In his last years he was an invalid and he died at Bournemouth on 1934 August 17. He is survived by his widow.

He was elected a Fellow of the Society on 1910 June 10.

The Reverend Father EDMUND GOETZ, S.J., was born in Alsace on 1865 November 10. He was educated for the priesthood, and was subsequently attached to the Zambesi Mission. At a later period he is found in 1902 at Georgetown, Washington, D.C., where he worked under Father Hagen. It may well be surmised that the influence of the future Director of the Vatican Observatory was directed towards stimulating Goetz's astronomical inclinations, and on his return to the Zambesi in 1903 June, Father Goetz found himself in charge of the recently established astronomical and meteorological observatory at Bulawayo. The idea of establishing this observatory had been conceived by Father Sykes during his term of office as Superior of the Zambesi Mission. The Government supplied a convenient site with a comfortable dwelling-house, and the new observatory was soon well equipped as far as Meteorology and Terrestrial Magnetism were concerned. At first the astronomical work was confined to naked-eye observations, but at a later date a 5-inch equatorial by Cooke was acquired. This instrument, however, lacked suitable accommodation, and it was not till 1913 that a building and dome were erected, the necessary funds being subscribed by leading business interests in Bulawayo in recognition of the work done for the public by the observatory.

In addition to his routine duties at the observatory Goetz found that other demands were made on his time. In 1909 he was asked to obtain latitudes and other observations along the projected railway line from Broken Hill to Katanga in the Belgian Congo, and this surveying expedition lasted about two months. In 1914 May he was engaged, in participation

with Mr. Wood of the Johannesburg Observatory, in a magnetic and astronomical survey of Barotseland, Goetz being responsible for the magnetic part of the work. He was an active member of the Rhodesian Scientific Association.

The last years of Goetz's life were spent at Salisbury, Rhodesia, where he was mainly occupied in teaching Mathematics and French at St. George's College. He died of pneumonia on 1933 August 19, and was buried on the following day in the cemetery at Chishawasha.

He was elected a Fellow of the Society on 1903 November 10.

SIR HORACE LAMB, elected a Fellow on 1919 February 14, died at Cambridge on 1934 December 4. He was born on 1849 November 27, at Stockport, and was educated at Stockport Grammar School, the Owens College, Manchester (now the University), and Trinity College, Cambridge, where he gained the Smith's Prize and was elected Fellow. After a short period of teaching at Cambridge he went, at the age of thirty-one, to Adelaide as Professor of Mathematics : while there he published his first book, on the motion of fluids, which grew in later editions into his treatise, of world-wide fame, on Hydrodynamics. Like his later books on the calculus and various branches of applied mathematics, it is characterized by the lucidity, easy style and wise selection of matter that were also marked features of his lectures.

In 1884 he was elected F.R.S., and in 1885 he returned to Manchester to succeed his old teacher, Barker, as Professor of Mathematics. There his main life-work was done, in developing an important school of mathematical studies, in teaching mathematics with great success also to students of engineering, physics and chemistry, in helping to build up a great university from small beginnings, and in his own important researches. These lay mainly in the fields of hydrodynamics, electromagnetism, tidal theory and seismology ; many of his papers had an important bearing on geophysics, and some, though to a less extent, on astronomy. The distinction of his work was recognized by many universities and scientific societies in Britain and abroad by the conferment of honorary degrees or other tokens of esteem. The Royal Society awarded him a Royal Medal in 1902, and its highest honour, the Copley Medal, in 1923.

He retired from his chair at Manchester in 1920, and returned to live at Cambridge. There his old college elected him an Honorary Fellow, and for a time he gave occasional courses of lectures in the University of Cambridge. During and after the War he took an important and highly valued part in the guidance of aeronautical research. In 1925 he was President of the British Association at its Southampton meeting. He was knighted in 1931.

He married in 1875, at the age of twenty-six. His home life was happy and hospitable, and he and his wife had the satisfaction of seeing several of their seven children attain distinction in various ways.

As seen by his students he presented a short sturdy figure of much dignity, in manner somewhat aloof and at times severe, but friendly to those

who came into personal association with him. That he remained very human was evident to all on those many occasions in his lectures when, with a merry twinkle in his eye, he gave play to his keen sense of humour. The regard and affection of his students was manifested by a presentation made to him on his eightieth birthday by a wide circle of his past pupils.

In committee or in debate he spoke seldom, but always with influence and weight. In matters of policy he was conservative. He was reserved, dignified and modest, a man of wide culture, well travelled and well read. His old age was ideal in that he preserved his powers of mind and enjoyment, his wide interests, his humour and enjoyment of humour, to the end. His last mathematical paper, published only a few weeks before his death, shows the analytical power and lucidity which characterized all his work. He died without serious pain or illness, full of years and honour. S. C.

WILLIAM RALPH MECHAELIS died after a brief illness on 1933 September 24. Born fifty-five years ago in Dunedin, Mechaelis was trained for the teaching profession at the Dunedin Training College and Otago University. In 1923 he was appointed rector of the District High School at Alexandra. He took a very prominent and active part in the social life of his district, serving on many and various committees.

Mechaelis, who was elected a Fellow of the Royal Astronomical Society 1926 February 12, was also a keen supporter of Astronomy in New Zealand. He was a member of the New Zealand Astronomical Society.

MARIA VICTORIA VICENTA DE RIVAS was born in London in 1864. Her father was a Spaniard, Don Vicente M. de Pereda, who married an English wife and settled in London, where his daughter was born and spent her childhood. In 1881 she married the Rev. P. J. Donovan, then curate at Christ Church, East Greenwich, afterwards vicar of Turnham Green. He died in 1906; at the end of that year she married Mr. C. F. Becher, an engineer in the service of the London County Council. The Spanish title of Countess de Rivas descended to her on the death of her father.

Her astronomical study was confined to such observations as could be made without instruments; thus she took part in the examination of the earliest age at which the young moon could be seen, a problem which attracted attention some time ago, in the hope of throwing light on the commencement of the month in ancient calendars. She had numerous other interests, such as music, painting, and the study of the Scriptures in the original languages.

She took a keen interest in the welfare of the railwaymen on the Southern Railway, and was elected an honorary member of the Associated Society of Locomotive Engineers and Firemen. A joint letter by representatives of this body after her death testified to their appreciation of her efforts for them.

She was elected a Fellow on 1922 May 12, and was a regular attendant at the meetings. She died in February 1934. She leaves a son by the first marriage, and a daughter by the second one. A. C. D. C.

COMMANDER JOHN ARCHIBALD RUPERT-JONES, R.D., R.N.R., was born at Sandhurst 1874 January 2. He was the son of Professor Thomas Rupert-Jones, F.R.S., the well-known geologist. Educated at Christ's Hospital, where he won the Founder's Medal, he went to sea at an early age, and served in the South Australian wool clippers. He rapidly rose to the rank of master mariner, and was in command of a cable ship for some years. In 1901 he was Government Pilot and Harbour Master at Aden, where he also carried out important survey work. He specialised in hydrography, and was engaged in extensive survey work in H.M.S. *Eleanor* on the coasts of Labrador and Newfoundland, and also in the West Indies. At the outbreak of the Great War he held the rank of Lieutenant R.N.R., and was appointed to H.M.S. *Sutlej*, and later was First Lieutenant in H.M.S. *Crescent*. His war service in Gallipoli, Archangel, and other theatres of war gained him two steps in rank and several mentions in despatches. After the war he carried out private survey work, and in 1925, on the recommendation of the then Hydrographer to the Navy, Rear-Admiral Sir H. P. Douglas, was appointed Hydrographical Surveyor to the Southampton Harbour Board, to take charge of the Board's very extensive schemes for dredging and deepening the port. Dredging schemes involving an expenditure of nearly half a million pounds were initiated by Commander Rupert-Jones and carried out under his constant supervision. He soon secured a remarkable grip of the facts connected with the waterway, and was thoroughly imbued with the great possibilities of the port. His energy was untiring, and his thoroughness and attention to detail were so great that it was said that there was no nook or cranny in the whole stretch of Southampton Water that he had not visited personally.

It was while he was engaged in studying plans of his work that he suddenly collapsed in his office on 1934 February 5, and died from heart failure in a few minutes. He was a man of remarkable attainments and varied interests, and was greatly beloved by all who worked with him. The chief interest of his life was the study of tides, on which he had written several treatises (privately published), especially in connection with the double tides of Southampton Water. Another hobby was the history of ships, on which he was a perfect mine of information ; he compiled a card index of almost every British merchantman built in a British yard from the Tudor age to the present day, and contributed many articles to the Press on maritime history. His paper on "The Physical Characteristics of Southampton Water," written in 1929 in collaboration with Mr. G. H. Daysh, foreshadowed the possibilities of future expansion of the port, which have been remarkably fulfilled.

He was elected a Fellow of the Society on 1921 January 14.

SIR ARTHUR SCHUSTER, F.R.S.—By the death of Sir Arthur Schuster we have lost one of our oldest and most distinguished Fellows. His scientific activities had a very wide range, including the electric discharge through gases, spectroscopy, solar research, terrestrial magnetism and meteorology. He was an excellent teacher, and he and his colleague

Sir Horace Lamb sent from Manchester University a succession of brilliant pupils. The value of international co-operation in scientific research appealed strongly to him, and he spared no effort to promote suitable associations before the War and to re-establish good relations afterwards.

Arthur Schuster was born at Frankfort-on-Main on 1851 September 12. He was the second son of Francis Joseph Schuster, of the firm Schuster & Sons, merchants and bankers. A full and interesting account of his early life is given in *Biographical Fragments*, published in 1932 November. He relates his experiences at the Frankfort Gymnasium which he attended between the ages of twelve and sixteen. He saw the entry of the Prussian army into the free city of Frankfort during the war with Austria in 1866. Frankfort then became a Prussian town. Schuster's father decided to emigrate rather than adopt Prussian nationality, and became a senior partner in the branch of the firm which had been established in Manchester.

Before Schuster came to Manchester he was sent for two years to Geneva to learn French. These he spent very happily in the house of a Swiss Pastor and attended lectures at the "Academy," the predecessor of the University. The lectures of Plantamour, a pupil of Bessel, were given at the observatory and here Schuster acquired a knowledge of elementary astronomy and of the routine work of the observatory. He stayed at Geneva till 1870 May, when he came home and entered his father's business. But the prospect of a business career was unattractive to him, and after a year his father, on the advice of Roscoe, agreed that he should attend the classes of Balfour Stewart on Physics and of those of Thomas Barker on Pure and Applied Mathematics at Owen's College. His first research in 1872 was an attempt to show that the spectrum of nitrogen consisted of bright lines, unaccompanied by the band spectrum which he attributed to the oxides of nitrogen. By heating nitrogen in a Geissler tube in contact with metallic sodium he hoped to eliminate the band spectrum. This experiment was not considered conclusive, as other lines not due to nitrogen appeared (probably argon).

In 1872, on Roscoe's advice, Schuster went to Heidelberg with introductions to Kirchhoff and Bunsen, and obtained the degree of Ph.D. after a year's work. Next year he was demonstrator in the Physical Laboratory of Owen's College, and spent the following summer at Göttingen in Weber's laboratory and the winter at Berlin under Helmholtz, returning to England at the end of 1874.

Schuster's introduction to astronomical research came in 1875. Near the end of 1874 he received an invitation from Norman Lockyer to take part in an expedition to Siam to observe the eclipse of April 6. Lockyer proposed to photograph the spectrum of the Corona, an ambitious and perhaps impossible project. It would be necessary to start on February 11. Unfortunately before this date, Lockyer found himself unable to leave England, and Schuster at the age of twenty-three was placed in charge of the expedition. A most interesting account of the difficulties, as well as of the pleasant incidents of the expedition, are given in *Biographical*

Fragments. The spectrum of the Corona was not obtained on wet collodion plates, but successful photographs were taken of the Corona and useful visual observations were made. Returning through India he took part in a venturesome journey over passes in the Himalayas from Simla to Srinagar, the capital of Kashmir. Schuster's interest in the Corona and the Chromosphere took him to the eclipses of 1878 in Colorado, 1882 in Egypt and 1886 in the West Indies. In 1878 he found from visual observations no absorption lines in the continuous spectrum of the Corona but a faint indication of the bright green line. In 1882 he obtained excellent photographs of the Corona (with a comet near the Sun) and measured 30 lines on a photograph of the Corona and chromospheric spectrum. At the eclipse of 1886 he also obtained excellent photographs of the Corona.

In the *Monthly Notices* of 1879 December he published a paper "On the Polarisation of the Solar Corona." Here he showed in what part of the Corona polarisation due to scattering by small particles would be most intense, depending on the density of the Corona at different distances from the Sun.

On his return from Siam in 1875 he became a demonstrator at Owen's College. One course of lectures he gave was on Maxwell's Theory of Electricity, and among his pupils was Sir Joseph Thomson. He then worked about five years at the Cavendish Laboratory first under Maxwell and later under Rayleigh, with whom he took part in the determination of the Ohm. He gave courses of lectures on "Radiation." In this he included spectroscopy, a word which he introduced in preference to "Spectrum Analysis" as indicating its use for physical research rather than chemical analysis.

In 1881 he was appointed Professor of Applied Mathematics at Owen's College, and in 1888 became Langworthy Professor of Physics in succession to Balfour Stewart. Here he stayed till 1907, when he was succeeded by Professor (now Lord) Rutherford.

His most important work was on the discharge of electricity through gases, the subject of two Bakerian lectures he gave in 1884 and 1890. He showed that a luminous discharge put the gas temporarily into a conducting state, due to the presence of charged ions. This was at a time when ionizing radiation was unknown.

In presenting the Copley Medal to Sir Arthur Schuster in 1931 the President of the Royal Society said :—

"He was the first to show the important information to be got by measuring quantitatively the magnetic deflection of cathode rays. He showed by combining the measurement with the potential difference which generates the rays that it was theoretically possible to determine without ambiguity the velocity and ratio of the charge to mass of the particles constituting the corpuscular stream. The theory of the method has stood the test of time. He failed in the application of the theory to his own experiments because he attached too much importance to the possible action of residual gas in depriving the particles of their full velocity. Nevertheless the steps

he took were a fundamental contribution to the line of work which led to the discovery of the electron."

Schuster maintained his early interest in spectroscopy. Independently, but subsequently to Rydberg, he discovered the relationships between the different series of spectral lines. In 1909 he brought out his *Theory of Optics* which still maintains its hold with advanced students. He developed a most interesting analogy between optical periodicity and the periodicities which have been frequently searched for and occasionally found in various statistics. The periodogram gives a criterion for results hitherto generally found by graphical methods. He applied this method to statistics of sunspots, but failed to discover any period comparable in importance with that discovered by Schwabe.

In 1905 he published in the *Astrophysical Journal* "Radiation through a Foggy Atmosphere," a paper which has become classical in researches on stellar atmospheres.

To his interest in Physics and Astronomy he added what is now generally called Geophysics. In 1889 he showed that the daily variation of terrestrial magnetism was caused by electric currents high in the atmosphere. He was dissatisfied with the usual method of determining the horizontal force of the Earth's magnetism, and sketched out an instrument with which this quantity could be more accurately and expeditiously measured by comparison with the field produced by an electric current of known amount. In co-operation with Sir Frank Smith a beautiful instrument was designed and constructed at the National Physical Laboratory. This instrument is now in use at the Abinger Magnetic Station of the Royal Observatory, Greenwich, and a number of similar instruments have been made for other observatories. He was interested in Seismology and presented to the Eskdalemuir Observatory a seismograph of the Galitzin type. He served from 1900 to 1932 as a representative of the Royal Society on the Meteorological Office Committee. In 1905 he endowed a Lectureship in Meteorology at Manchester, and later as a member of the Universities Commission advocated the establishment of a Lectureship in Meteorology at Cambridge.

In addition to his scientific research and professional duties he did a large amount of administrative work. He took a leading part in the conversion of the Victoria University into the three Universities of Liverpool, Manchester and Leeds. He attended the preliminary meeting of the Association of Academies at Wiesbaden in 1899. The statutes were drawn up in Paris in 1901, and at the second meeting in London in 1905 he took a leading part. He was usually one of the Royal Society representatives in the triennial meetings of this association, and gave to the Society a sum of £3000 to defray the expenses of delegates. Of more interest to astronomers is the International Union for Solar Research. This Union was founded on the initiative of Dr. Hale at St. Louis in 1904, the provisional programme being drawn up by Hale, Schuster and Arrhenius. Very useful and attractive meetings were held at Oxford in 1905, Meudon in 1907, Mt. Wilson in 1910 and Bonn in 1913. It was truthfully said by one of the delegates at Bonn that Hale was the father and Schuster the mother of the Union.

He was Secretary of the Royal Society from 1912 to 1919, and Foreign Secretary 1920–1924, and President of the British Association at Manchester in 1915. During the War he was distressed by the unreasonable prejudice against his German origin. In his *Biographical Fragments* he records with pleasure a kindly action of Lord Roberts which indicated that he, at any rate, had no doubt of Schuster's loyalty.

After the War he took a large part in the formation of the International Research Council. A preliminary meeting was held in London, 1918 October 9–11, followed by one in Paris, November 26–29, when Schuster was appointed Secretary. National Research Councils were appointed for different branches of science. Draft statutes of the International Unions of Astronomy and Geophysics were drawn up, and considered at the first general meeting of the International Research Council held in Brussels in 1919 July. Schuster was General Secretary of the Executive Committee till 1928, when he was succeeded by Sir Henry Lyons. The first meeting of the International Astronomical Union was held in Rome in 1922, followed by meetings at Cambridge in 1925, Leiden in 1928, and Cambridge (Mass.) in 1932.

Schuster was the recipient of many honorary degrees and received the Royal, Rumford and Copley Medals of the Royal Society. He was knighted in 1920.

In 1887 he married Cary, eldest daughter of the late Mr. George Loveday of Wardington, Oxfordshire, and had one son and four daughters. During many years they lived at Kent House, Victoria Park, Manchester, where many students and colleagues enjoyed and appreciated their hospitality. His pupils readily went to him for advice, and he followed their subsequent careers with great interest. In 1910, after his retirement, he revisited India and gave a series of lectures on "The Progress of Physics, 1875–1910." In 1914 he made his home at Yeldall, near Twyford. He continued in active work till about 1930. He died on 1934 October 14 at the age of eighty-three after a serious illness which extended over several years.

He was elected a Fellow of the Society on 1877 December 14, and for the five years 1914–1919 was Foreign Secretary.

F. W. D.

DUNCAN McLAREN YOUNG SOMMERVILLE was born at Beawar, Rajputana, on 1879 November 24. He was the son of the Rev. Dr. James Sommerville. He was educated for four years in a private school in Perth, Scotland, and afterwards at Perth Academy. He then proceeded to St Andrews University, where he took first-class honours in mathematics and natural philosophy. In 1905 he proceeded to the degree of Doctor of Science, his thesis dealing with Topology in Non-Euclidean Space. This choice of subject foreshadowed some of his later work, and in 1914 he published *Elements of Non-Euclidean Geometry*, a small book which appeared at a time when metrical systems other than that of Euclid were known only to a limited circle. Other textbooks subsequently published were *Analytical Conics* (1924), *Introduction to the Geometry of*

n Dimensions (1929) and the recent *Three Dimensional Geometry* (1934), which appeared after his death.

In 1905 Sommerville was appointed a mathematical lecturer at St Andrews. He filled this post until 1915 when he became Professor of Pure and Applied Mathematics in Victoria University College, Wellington, New Zealand, where he gained a reputation as a great teacher and a helpful friend to his pupils. It was in the realms of geometry, and especially in the non-Euclidean geometries of Riemann and Lobatchewsky that he found full scope for his genius, but he had considerable interest in other sciences. He was one of the founders of the New Zealand Astronomical Society and was also its first Secretary. He was elected a Fellow of the Royal Astronomical Society on 1926 April 9, but previously to that date two papers by him had appeared in the supplementary number of the *Monthly Notices* for 1919. The titles of these papers were "A Graphical Method of Predicting Occultations" and "The Form of an Eclipse Chart near the Pole." The fact that these papers were the first and last by Sommerville that appeared in the *Monthly Notices* is to be ascribed to the many interests he had apart from his own specialty of geometry. He was generally interested in physical science, and in 1924 he was President of Section A of the Australasian Association for the Advancement of Science on the occasion of the Adelaide meeting. He took an active interest in adult education in New Zealand. He was also a capable artist, and in the course of years he produced a pleasing collection of water colours of New Zealand scenery.

In addition to his books Sommerville was the author of more than thirty original papers and notes which have appeared in various journals. Naturally most of these deal with geometrical subjects. He died suddenly of heart failure on 1934 January 31, and his loss will be mourned by the mathematical world and by his old pupils who had come to regard him with esteem.

The Rev. WALTER EDWARD STEWART was elected a Fellow of the Society on 1888 March 9. During a considerable portion of his life he was a keen amateur observer and was the possessor of a Cooke 5-inch equatorial with which he worked a great deal during the years 1890 to 1904. At this time he lived at Hurworth-on-Tees and was the vicar of the neighbouring village of Eryholme. The telescope was eventually bought by subscription and set up in Darlington Park.

From 1905 to 1912 Stewart was vicar of Longney, Gloucestershire. His health and sight then began to fail and he retired to St. Philips, Scalby, near Scarborough. He died on 1934 January 24, and was buried at Eryholme, the scene of his earlier labours.

WILLIAM MORGAN TATE-STOATE died on 1934 March 10. He was the youngest son of Richard and Elizabeth Tate-Stoate of Clifton. He graduated at Trinity College, Dublin, having specialised in experimental physics and obtained an appointment in 1877 at Coatham Grammar School. He resigned this post two years later to be ordained, and was eventually

vicar of Pebworth from 1904 to 1924. Upon retiring he and his wife took up residence at Blockley, Gloucestershire, where he remained until his death. In 1901 he had been elected a member of the Royal Irish Academy, and he was elected a Fellow of the Royal Astronomical Society on 1932 April 8.

He married in 1894, his wife being the daughter of the late Lieutenant-Colonel Hugh Rigg of Cronrigg Hall, Westmoreland.

HERBERT GERARD TOMKINS, C.I.E., was born on 1869 April 21 and died on 1934 July 17. He was the eldest son of the Rev. Gerard W. Tomkins, Vicar of Gorleston, near Yarmouth. His boyhood was spent in England, but at the age of fourteen he was taken by his parents to India, where he received his education, and where he was destined to spend the greater part of his life. When twenty two years old he entered the service of the Financial Department of the Indian Government, and served successively in the Punjab, the United Provinces and Bengal, holding the office of Accountant-General of the Province of Bengal at the time of his retirement on 1922 May 6. In recognition of his services he was awarded a Companionship of the Indian Empire at the Great Durbar of 1911. It may be noted that his three brothers also all achieved distinction in the Indian Services.

He became interested in astronomy at an early age, and followed its study with characteristic enthusiasm, an enthusiasm which may be judged from the fact that he founded and became first President of an Astronomical Society of India, which was in existence for a number of years, but unfortunately did not long survive the retirement of its founder. In astronomy he concentrated his attention on one line of research—the Moon, and in particular its physical features. This may have been because in the course of his official journeys in Northern India he observed that the crystalline deposits of saltpetre met with in that region bore some resemblance to the bright rays on the Moon's surface, and he put forward the suggestion that they might both have a similar origin. This and other ingenious theories are published in papers contributed to the *Monthly Notices* and the *Journal of the B.A.A.*

With the pursuit of his theories came the need to improve his instrumental equipment, and not having the necessary funds for the large telescope he desired, he applied his natural ingenuity and mechanical skill to the design and construction of a 24-inch reflecting telescope. The greater part of the work, including a grinding and polishing machine for the figuring of the mirror, was carried out in India. On his retirement he settled at Dedham, near Colchester, where he completed the work. It should be mentioned that his activities were severely hindered by the fact that twenty-two years ago, through an accident, he practically lost the use of his left arm, such use as remained being due only to his courage and will power; yet at the time of his death he was engaged on the grinding of a new 30-inch mirror to replace the 24-inch. Since the completion of the telescope he worked with it on every favourable occasion, securing a great number of excellent photographs, which his widow has presented to the Society for

the benefit of any who have occasion to study the lunar features. The telescope is now to find a home at Kyoto University, Japan.

Tomkins was enthusiastic and companionable, and loved to entertain his friends, and many will retain pleasant memories of week-ends spent at Dedham discussing his photographs, admiring his garden, and enjoying the music for which he had so great a passion.

He leaves a widow, who throughout his life has been a true helpmate, and two sons, both of whom are in the Indian Services.

He was elected a Fellow of the Society on 1907 June 14.

C. D.

MICHAEL HERIOT HUTH WALTERS was educated at Eton from 1922 to 1927. He then proceeded to King's College, Cambridge, and in 1931 he took Part II. of the Mathematical Tripos, his name appearing among the wranglers. He was awarded a Martin Thackeray Research Studentship. In 1933 he obtained a Rayleigh prize, and was awarded a Proctor Visiting Fellowship at Princeton University, where he continued his astronomical research. A promising career was cut short by his sudden death at the age of twenty-five on 1934 March 26.

Walters contributed two papers to the *Monthly Notices* (*M.N.*, **92**, 786, 1932 and **93**, 28, 1932). These deal with the effects of close stellar encounters on the eccentricity and semi-axis major of a spectroscopic binary. The second paper corrects a slip in the first and extends the investigation. He found that there was no appreciable effect on the dimensions of the orbit, but that with a star density of 10 stars per cubic parsec an interval of the order of 10^{13} years would suffice to produce an appreciable increase in eccentricity. Nowadays an interval of 10^{13} years is considered too generous an allowance, but Walters pointed out that it would be reasonable to suppose that in the early stages of the galaxy the stars were much more closely packed together and that large changes in eccentricity might therefore be expected in a shorter interval. Had he lived he would no doubt have carried on this and other researches.

EDWARD FAWCETT WHITE was born at Plymouth on 1869 August 6. He came to Bristol at an early age and there received his education. At a later age he assisted his father in conducting the Naval School, Prince Street, Bristol, and on his father's retirement he took charge of the School. He was eventually appointed lecturer in navigation and nautical astronomy at the Merchant Venturers' Technical College, Bristol, and he held this position for thirty years up to his death on 1934 June 29.

In the course of his career White prepared hundreds of pupils for the Mercantile Marine. He was responsible for the formation of the Merchant Venturers' Old Boys Society, of which he was secretary up to the date of his death. In this capacity he was able to keep in touch with old boys in all parts of the world.

He was also responsible for the formation of the Bristol Wheelers' Cycling and Rifle Clubs. He instructed many in the use of the rifle and was

complimented for his zeal by the late Lord Roberts. His wife predeceased him by twelve days, and they leave one son and four daughters.

He was elected a Fellow of the Society on 1902 February 14.

EDOUARD BENJAMIN BAILLAUD was born on 1848 February 14 at Chalon-sur-Saône. Excepting Deslandres and Donner very few of his contemporary astronomical colleagues survive. They included Abetti, Backlund, Belopolsky, Celoria, Christie, Gill, Hagen, Paul and Prosper Henry, Kapteyn, Knobel, Pickering and Seeliger, with most of whom he was associated in the work of the Astrographic Catalogue and Chart. In 1866 he was a student at the Ecole Normale Supérieure, and 1869 was Professor in the Lycée Fontane, till in 1872 he became Elève Astronome at the Paris Observatory, becoming Aide Astronome in 1874. In 1877 he lectured at the Sorbonne on dynamical astronomy as substitute for Leverrier. After Leverrier's death in September of the same year, Tisserand was appointed to the Paris Observatory and was succeeded by Baillaud at Toulouse. Here Baillaud stayed from 1878 to 1907, when he was appointed Director of the Paris Observatory. He was interested in Planetary Theory and wrote on the Development of the Perturbing Function, investigated the orbits of the five interior Satellites of Saturn and discussed the numerical calculation of definite integrals by methods of quadrature. He made a long series of observations of the Satellites of Saturn and made a few measures of double stars, but was generally more interested in the discussion of observations. On his staff at Toulouse were Bigourdan, who began his interest in historical astronomy by a History of the Toulouse Observatory, and Andoyer, who wrote papers "On the General Formulæ of Celestial Mechanics" and "Inequalities in the Longitude of the Moon," which he compared with Delaunay and thus checked the formulæ of that theory. The main work of the Toulouse Observatory was observations of Sunspots from 1879 onwards, equatorial observations of satellites and double stars and meridian observations, including observations of the Moon. When the project for the Carte du Ciel was originated, Baillaud joined with enthusiasm and undertook the zone from 5°–10° N. dec. The catalogue plates centred at 5°, 7°, 9° were duly photographed, measured and published, and the charts were also taken in hand. Baillaud realised the importance of having reference stars at the same epoch, and with a new meridian circle 3719 stars were observed between the years 1891 and 1900.

The University of Toulouse availed itself of Baillaud's administrative ability and after a few years chose him as Doyen of the Faculty of Science. A large increase in the number of chairs was a result, and of special interest to astronomers is the establishment, due to his foresight, of an observatory on the Pic du Midi.

In 1907 Baillaud succeeded Loewy as Director of the Paris Observatory. This observatory, founded by Louis XIV in 1667, is in the heart of Paris, and in modern times has suffered from the illumination of the city and the vibrations caused by the street traffic. Baillaud was anxious to move to a more suitable site, but it has been left to his successor to establish a new

observatory at Forcalquier in the Basses-Alpes. He was in close relationship with his friend General Ferrié, who was in charge of the wireless station at the Eiffel Tower. When the emission of time-signals was started by General Ferrié, he naturally applied to Baillaud for accurate time from the observatory. The possession of a very deep cellar in which the clocks were installed was of great service in keeping the rates fairly constant between successive astronomical determinations, so that the times sent from the Eiffel Tower were usually very accurate. When the War came, the younger members of the staff including Baillaud's two sons were called up. He kept the time-signal service of the Eiffel Tower all through the War, frequently making the adjustments with his own hands. He strongly supported General Ferrié's scheme of a complete girdle round the world of accurately determined longitudes, carried out in 1926 and repeated in 1933.

Since the foundation of the Bureau International des Poids et Mesures, with its centre at Breteuil in 1875, and still more since the inception of the Carte du Ciel in 1887, Paris, till the War, became the international astronomical centre. In 1909 a Conference of the Carte du Ciel was held, at which the results obtained from the observations of Eros in 1900–1 were under discussion. In this connection Mr. Hinks writes: "I can never be grateful enough to Baillaud for the way he supported my Eros work." In 1911 the Directors of the National Ephemerides met a number of leading observational astronomers to secure a suitable division of work by the different countries resulting in a marked increase in the data of the Almanacs. In the same year an informal conference on the dissemination of time by wireless signals met, and in the following year a more formal conference was called together. A Commission Internationale de l'Heure was created, with a bureau at Paris. At these conferences Baillaud presided with dignity and unfailing courtesy. In 1913 he attended the meeting of the Solar Union at Bonn, and the writer remembers an eloquent speech made by Baillaud at a farewell banquet at Cologne on the effect of such conferences not only on astronomy but also in tending to peaceful and happy relationships between nations. The War followed in 1914. In 1919 a new start was made by the formation of the International Research Council, and by it the International Astronomical Union and other similar unions were constituted. Baillaud, who had been at the 1887 conference when the Carte du Ciel was initiated, was elected the first President. He conducted the meeting at Rome in 1922 with the urbanity and kindly feeling which was natural to him. At this conference Professor Turner succeeded him as President of the Commission of the Carte du Ciel, and as a tribute to his previous services Baillaud was unanimously elected Président d'Honneur of the Commission. In his final address to the Union he maintained that in spite of the difficulties and sufferings of the War he was still an optimist and looked for a happy future for astronomers and the world at large. He attended the meeting of the Union at Cambridge in 1925 and was given the Honorary degree of Sc.D. by the University. He continued in the directorship of the Paris Observatory till 1926 and was given the title of Honorary Director.

Madame Baillaud died six years before the retirement of her husband, making a break in a very happy family life. They had a large family, of whom M. Jules Baillaud, Assistant at the Paris Observatory, and M. René Baillaud, Director of the Observatory of Besançon, are distinguished astronomers. The Baillauds extended the most friendly welcome and kindly hospitality to the astronomers attending the many conferences in Paris. The writer and many others remember with special pleasure how they were invited to join the large family circle at Sunday evening supper at the observatory.

M. Baillaud received the Bruce Medal of the Astronomical Society of the Pacific in 1923 and was elected an Associate of our Society in 1908. He died on 1934 July 8 at Toulouse, where he had made his home after his retirement.

F. W. D.

JULIUS BAUSCHINGER was born on 1860 January 28 at Fürth, in Middle Franconia. From his father, who was an eminent physicist, he inherited his strong leaning towards mathematical science and his ability for teaching. From 1879–1883, after attending school in Munich and completing a year of military service, he studied at the Universities of Munich and Berlin. The professors of astronomy who definitely influenced his career were Seeliger, Foerster, Tietjen and Auwers. In 1883 he completed his last piece of work as a student, namely the investigation of the motion of the planet Mercury—a work which even to-day is still of positive value.

Bauschinger's scientific life may be divided into four periods. At Munich from 1883–1896, first of all as Assistant and from 1886 onwards as Observer, he was concerned chiefly with meridian astronomy. Several publications of the Munich Observatory give evidence of this, as for instance the two Munich star catalogues, the investigation of the flexure of meridian telescopes, and, above all, a new determination of the constants of refraction, which was the first modern determination of these. At the same time he extended his sphere of activity by becoming a lecturer at the University and at the Technical High School. He first turned his attention to work on the determination of orbits when investigating the periodic comet 1889 V (Brooks), and it was in this sphere that later he was to achieve his greatest success. By the zeal he showed at Munich for research and for teaching it was recognised that he possessed great ability for organising on a large scale and a capacity for scientific calculation.

At the age of thirty-six Bauschinger became Director of the *Astronomisches Rechen-Institut* and Professor of Theoretical Astronomy at Berlin University. Here he found many matters in urgent need of organisation. In May 1896 he took part in the Paris Conference for the adoption of astronomical constants, at which he came in contact with the directors of other ephemerides—Downing, Loewy, Newcomb and others. The decision of the Conference to introduce the Newcomb-Hill tables for the major planets and Auwers's new fundamental catalogue caused considerable alterations to be made in the basic construction of the *Berliner Jahrbuch*. For

the minor planets it was found necessary to organise fresh observations and computations. To carry out this work many more assistants on the staff of the Institut were required. The result of Bauschinger's efforts was that the Institut was separated from the Berlin Observatory and established as a large independent institution. In addition to this activity in organisation, he investigated several special problems connected with the determination of orbits, and also taught extensively. He made good use of the experience gained in research work, teaching, and many years of practical computation at the Institut in the production of his most important works, *Tafeln zur theoretischen Astronomie* and *Bahnbestimmung der Himmelskörper*—works that have linked for all time the name of Bauschinger with the theory and practice of the determination of orbits. For twenty years these works held the leading place, and influenced a wide circle of students. The latest constants and the experience gained from many years of practice were utilised in the Tables, which were re-calculated, extended or put into more convenient form. His text-book embodied the most recent methods for the determination of orbits of planets, comets, meteors, satellites, and double stars, and showed his preference for the geometric-synthetic form ; his exposition was particularly pleasing and clear. In collaboration with J. Peters he published the standard work on logarithmic trigonometrical tables to eight places of decimals.

In the year 1909 Bauschinger accepted a post at the University Observatory at Strasbourg. Here he undertook the making up of the great arrears in the reduction of observations accumulated since 1880, the continuation of the observing programmes on the photometry of nebulæ and observations of double stars, and a new programme for the determination of absolute positions of stars, freed from proper motion, for the purpose of obtaining a satisfactory determination of the constant of precession. At the same time he worked at the theory of determination of orbits, and also at the determination of latitude. During the War his activities practically ceased.

After the War, in 1920, Bauschinger, now sixty years old, left Strasbourg to take a post at Leipzig. Here he worked up one part of the observations obtained at Strasbourg. Immediately afterwards he was put in charge of the re-observation of the A.G. Catalogue. Towards the end of his scientific career he published two profound encyclopædic articles on the determination and interdependence of astronomical constants, the rotation of heavenly bodies, precession and nutation, and also a new edition—practically unaltered —of his text-book on orbits.

Bauschinger's contributions to astronomical science lie not in any new, revolutionary or creative ideas, but in the fact that, by improving methods of observation and theory and by organising productive programmes, he added to the security of the foundations of classical astronomy.

Bauschinger's scientific work received recognition abroad as well as at home : he was elected an Associate of the Royal Astronomical Society in 1925, a member of the Sächsische Gesellschaft der Wissenschaften and a corresponding member of the Academies of Science at Munich and Berlin.

He died on 1934 January 21. G. S.

ARISTARCH BELOPOLSKY.—By Belopolsky's death on 1934 May 16, the Society loses one of its honoured Associates. His long-continued activity, reaching back to the days of pioneering work in spectral photography in the years about 1890, leads us through interesting times, in which the methods of determining stellar velocities in the line of sight were being developed. He took a notable part in the early discoveries of spectroscopic double stars.

His was a character of direct simplicity and geniality, such as it was a delight to experience, and it is a pleasure to recall. It is natural to remember him in his visits to this country in the company of Oskar Backlund, who was his devoted friend.

Aristarch Belopolsky was born at Moscow in 1854; and in 1873 he went to Moscow University, a student in astronomy and geodesy. He took his degree in 1876 with a dissertation on Sunspots and their motions. Two years later he became an assistant in the Moscow Observatory under Bredichin, and remained there for ten years, engaged in meridian work, photoheliographic and spectroscopic observations of the Sun, the photography of comets, and the study of motions on the surface of the Sun. It would seem that Belopolsky was thus acquainted with the astrophysical work which Bredichin was the first to introduce in Russia, in the form of spectroscopic observations of the Sun and of the tails of comets.

In 1888 he was appointed by Otto Wilhelm Struve to a permanent post at the Pulkovo Observatory; and when Bredichin succeeded Struve in the Directorship, Belopolsky was given leave of absence to go to the Astrophysical Observatory at Potsdam, where H. C. Vogel was engaged in making his fine spectrographic determinations of stellar velocities in the line of sight which resulted in observations of forty of the brighter stars. Belopolsky decided to have a facsimile of Vogel's spectrograph made at Berlin for attachment to the 15-inch refractor of the Pulkovo Observatory. One can imagine his frame of mind when he received from his Director an order "to employ all means without sparing money or time to adapt the spectrograph as quickly as possible to the great thirty-inch refractor." Then began a time of investigation of the colour curve of the large (visual) refractor—a work of the same kind as occupied the minds and time of most astrophysicists in those years 1890–97.

Belopolsky got to work and studied with good effect the spectra of the brighter stars. Among his notable successes we may refer to his discovery of the duplicity of the fainter component of the telescopic double star Castor (α Geminorum). He published a full account of his observations, from which he deduced a period of $2^{d}\cdot92$, and a movement of the line of apsides.

We may also refer to his measures of the variable velocities of δ Cephei, η Aquilæ, β Lyræ, ζ Geminorum and ζ Herculis. His observations of P Cygni led him to the conclusion that when the spectrum of a star is made up of bright and dark components, great judgment has to be exercised in deciding what ought to be considered as the true centre of each of the overlapping components, a matter of great importance in observations of Novæ.

He devoted considerable time to devising an experimental proof of Doppler's Principle from observations of terrestrial objects, and succeeded in detecting by spectrographic observations the changes in the wave-length of light reflected many times between quickly rotating mirrors.

He was among the first to obtain by spectrographic observations a determination of the rotation of Saturn's rings, and the period of rotation of Jupiter. He also attempted by similar means to assign a period to the rotation of Venus. And he took part in determinations of the rotation of the Sun.

His discovery of marked variation in intensities of absorption lines in stars such as α Canum Venaticorum makes one realise his alertness in noticing any short-lived changes in the spectra of the eternal stars; and it leaves one wishing that it had been his lot to work in a place where atmospheric conditions were better than those at Pulkovo.

His whole output of publication is said to amount to more than 200 communications published (some in Russian, and others in German, French and English) in the *Annals* of Moscow Observatory, in the *Memoirs* and *Bulletins* of the St Petersburg Academy of Science, in the *Astronomische Nachrichten*, and in the *Astrophysical Journal*.

After the death of his friend Backlund in 1916 Belopolsky was elected Director of Pulkovo Observatory. He resigned the post in 1918 in order to carry on research at the Academy of Science. In 1931 he was made Honorary Director of the Pulkovo Observatory.

He was elected an Associate of our Society in 1910. H. F. N.

CARL VILHELM LUDVIG CHARLIER was born on 1862 April 1 in Östersund, the capital of the province of Jämtland in Northern Sweden. He was the son of the Inspector Emerich Emanuel Charlier and Aurora Kristina Hollstein. After having passed through the high school in his home town he matriculated at Upsala in 1881 September. His university career was thorough and unusually rapid; he was Cand. Phil. (corresponding to M.A.) at the end of 1882 and Lic. Phil. in 1886 March. On 1887 March 9 he made his public defence *pro gradu* of his thesis, "Untersuchung über die allgemeinen Jupiter-Störungen des Planeten Thetis." Owing to the quality of this work he was immediately appointed Lecturer at the University of Upsala. In 1890 he was observator (corresponding to chief assistant) at the Observatory of Upsala. This office he held till 1897, when he was promoted by the government to be Professor at the University at Lund and Director of the University Observatory there. In 1927 he retired on pension as Professor Emeritus. Having enjoyed unusually good health throughout his life he was struck down by an apoplexy in 1932 July. He died at Lund on 1934 November 5 and is survived by his widow, Siri Dorotea Leissner, and five daughters.

Among the many honours which fell to the lot of Charlier the following should especially be mentioned: the Memorial Medal of the Royal Physiographic Society at Lund in 1924, the Watson Medal of the National Academy of Sciences at Washington, D.C., 1924, and the Bruce Medal of the Astronomical Society of the Pacific, 1933. He was a member of the three

Academies of Sweden: the Royal Academy of Sciences and the Royal Academies of Upsala and Lund. He was also a member of the National Academies of Austria, Denmark and Norway, and was elected an Associate of the Royal Astronomical Society in 1908.

During his period at Upsala Charlier lived amongst a congenial circle of friends, generally known as the "Verdandists," after a society of students founded for the preservation and development of freedom of thought and its manifestation. This society advanced liberal and radical ideas, and from it many of the leading politicians of Sweden obtained their first impressions of public life and their first training in public speaking. Charlier did not take any active part in political life in Sweden, but he was true to the ideals of his youth and always kept an open-minded attitude towards contemporary movements for advancing new ideas and ideals. His interest in philosophical and religious problems was very keen, and among his papers we find one with the title: "Can there be Religion without Presumption of Divine Revelation?" About the same time he published his first investigation as to the possibility that the world has an infinite extension in space and time. In this paper (*Archiv. f. system. Philosophie*, Bd. 2, pp. 477–494, 1896) he reached the conclusion that the world has a finite extension in space. In 1922, when he returned for the third time to this fascinating question, he established his world criterion according to which an infinite world of cluster agglomerations may be built up, provided that

$$R_i/R_{i-1} > N_i^{\frac{1}{2}}$$

where N_i stars form a Galaxy G_i, and N_{i+1} Galaxies form together a Galaxy of the order $i+1$, and so forth. An analysis of the known facts as to the galaxies showed that our present knowledge is in harmony with the supposition which underlies the above-mentioned construction of an infinite world. It seems that the paper dealing with this theme has not yet received its proper recognition.

It was natural that the mind of the young Charlier should be attracted by the work of Hugo Gyldén, the famous Director of the Observatory at Stockholm (1871–1896). In his thesis we find Charlier as a pupil of Gyldén. During his first period at Lund Charlier inspired and directed a number of investigations in the domain of Celestial Mechanics. As far as he himself was concerned this work gave rise to, among other results, the extensive text-book: *Die Mechanik des Himmels—Vorlesungen*, Leipzig, 1902–1907; second impression 1928. He also published several papers dealing with the general rotational problem and (during his subsequent statistical period) papers on the multiple solutions in the determination of orbits, and on methods for deriving preliminary elements of orbits.

During his first decade at Lund Charlier had not found his proper sphere. Once in an astronomical circle he referred to this period with a melancholy smile, saying: "Well, it was at the time when we still dreamed of reaching the solution of the problem of three bodies."

It seems that the turning point in Charlier's scientific path is marked by the paper: "Researches into the Theory of Probability" (1906). The

theory of mathematical statistics has perhaps its very corner-stone in the famous theorem of J. Bernoulli. Although the subject has developed rather definitely along certain lines, a number of ingenious suggestions by Laplace had not been worked out until Charlier undertook the task of extending the theory. In the said memoir Charlier gives expression to his deep admiration of K. Pearson's "Contributions to the Mathematical Theory of Evolution," and says that his intention is further to develop the line of research laid down by Pearson and his school.

In numerous papers Charlier and his pupils have made important contributions to the problems of mathematical statistics. Of fundamental importance is the division of the frequency curves into three types, A, B and C. It is the first type which most nearly corresponds to the so-called normal distributions. It can be developed in a series of the normal distribution-curve and its derivatives. Finally, Charlier in collaboration with Dr. Marcel Riesz, Professor of Mathematics at Lund, succeeded in proving the convergence of the series of type A.

The application at Lund of mathematical statistics has in the first place aimed at contributions to the problems of stellar astronomy and above all to the "Construction of the Heavens." Charlier issued a number of memoirs dealing with the constitution of the Milky Way. The first (*Lund Medd.*, ser. ii, 8) does not lead to very remarkable results, partly on account of the rather uncritical use of the star counts of the Carte du Ciel. The second memoir (ser. ii, 9) gives an exhaustive discussion of the proper motion material in Boss's Preliminary General Catalogue. Here is established for the first time the antithesis to Kapteyn's famous two-stream hypothesis. Charlier sees in the determination of the constants of the velocity-ellipsoid the main task of the analysis of stellar motions.

The memoirs in the same series of 1916 and 1927 relate to the spatial distribution of B stars. Charlier has here applied one of Sir William Herschel's principles (M = const.) to a sub-group of stars where the assumption is statistically justified.

A masterly summary of his contributions as to the constitution of the Milky Way is found in the lectures given by Charlier, by invitation, to the California State University in Berkeley. The publication is generally referred to as Charlier's "California-Lectures."

A part of this work is also the extensive star-counts on the Franklin-Adams charts made in Lund under the direction of Charlier. It is to be regretted that these counts have not yet been finally reduced. The raw material is to be found in *Lund Medd.*, ser. ii, No. 31.

Some astronomers have remarked that in some astronomical papers by Charlier the mathematical statistics dominate somewhat at the expense of applied and observational astronomy. The remark may be justified in certain cases, but numerous papers by Charlier could be mentioned where the astronomical problem is certainly in the foreground. Among the statistical papers we need only mention the "Statistical Notes on the Draper Catalogue," giving numerous useful distribution tables and correlation surfaces on the basis of the New H.D. and involving an enormous amount of work.

The published papers and books by Charlier exceed 150 in number. It is not possible in this notice to give even a summary of his scientific achievements. As a theoretical statistician he rendered many excellent services to his country and university. Although not officially Professor of Statistics, he in effect performed that office. Several statisticians and government officials have had their training in statistics under Charlier. In 1926 through his efforts a chair in statistics and mathematical statistics was set up at Lund University. Charlier was also on several occasions called in as an expert to advise the Swedish Government. Thus he took part in discussions as to the arrangements for a money-lottery of the State and in several questions relating to pensions. He also arranged the present system of zone-tariffs for railway fares (starting from a certain minimum fare, the rate is reduced in proportion to the length of the journey).

He was perhaps not so deeply interested in the problems of practical astronomy as in the theoretical ones. But he certainly appreciated observational work and he always encouraged his co-workers to go in for extensive observing. Among the papers produced during his time at Upsala and Stockholm there are several discussing astrophysical problems and questions in stellar astronomy, founded upon original observational work. Charlier was one of the first who established a formula giving the connection between measured diameters of photographic stellar images and stellar magnitudes. He also made interesting deductions concerning the mathematical form of the laws of radiation.

It was to be expected that a man having the wide interests and learning of Charlier should appreciate studies in the historical development of astronomy. He made a translation into Swedish of Newton's *Principia* ("the most ingenious work ever written," as he used to exclaim enthusiastically). As a rule Charlier was not extremely enthusiastic in his statements or actions except when talk fell on torch-bearers such as Kepler, Galileo or Newton. His translation of the *Principia* was published (mainly at the expense of the Swedish Government) in the years 1927–31. The work is accompanied by portions of the excellent analytical translations which Charlier made of Newton's difficult pure geometric reasoning. This work is a worthy and devoted monument to one of the greatest of mankind.

Charlier was a brave and gallant nature but a man of considerable reserve ; he was something of the *noli-me-tangere*-type. But behind the intelligent-aristocratic surface and the proud manners there was a gentle nature and a sensitive soul. He had his disappointments, hardships and sorrows, but he never complained and he did not like sharing his troubles with all and sundry.

The keynote to Charlier's life certainly lay in the circumstance that his rich natural gifts were combined with a passion for work. When troubles came he worked still harder, and when his friends and pupils received their share of hardships he recommended to them work, work and work.

Charlier was widely known and had many friends among contemporary astronomers and other scientists. With his relatives and his country, international science joins in mourning him. K. L.

WILLEM DE SITTER was born on 1872 May 6 at Sneek in Friesland. He received his preparatory education at the Gymnasium at Arnheim, where his father was a judge, and then went to the University at Groningen. His intention was to become a mathematician, though he soon began to show an interest in physics and astronomy. Whilst still a young student, he obtained permission to assist in some of the experiments carried out by Haga, the professor of physics, and he began to work in the Astronomical Laboratory at Groningen, where Kapteyn was engaged on the measurement of the plates of the Cape Photographic Durchmusterung. It was more or less as the result of a chance meeting with Sir David Gill that de Sitter definitely decided to become an astronomer. In 1896 October Gill was on a visit to Kapteyn ; in his laboratory he found de Sitter at the measuring machine, engaged on the measurement of a plate. Gill had some conversation with him, and the following morning de Sitter, while having breakfast in his rooms, received a message that Gill wished to speak to him in the laboratory. De Sitter did not possess at that time the fluent command of the English language which he afterwards acquired ; Kapteyn was lecturing at the time and Mrs. Kapteyn acted as interpreter at the interview. Gill invited de Sitter to come to the Cape as a computer and, as de Sitter afterwards stated in a letter to Gill, "thereby complete my astronomical education—or rather begin it, for up to that time I had never made a specialty of astronomy and intended to become a mathematician." De Sitter decided, after consultation with his parents, that he would first pass his examinations preparatory for the doctor's degree, and then go to the Cape. He reached the Cape in 1897 August. The intention had been that he should make parallax observations with the McClean telescope, which had in 1894 been offered to the Cape Observatory by Mr. Frank McClean. But the telescope was not completed in time. De Sitter therefore assisted with the heliometer observations, determining the parallaxes of four stars and taking a share in the polar triangulation. He also occupied himself with a programme of visual and photographic photometry. The purpose of these observations was to determine the difference in colour between stars near the Milky Way and stars near the galactic poles : the problem had arisen in connection with Kapteyn's work on the C.P.D., Kapteyn having found that the C.P.D. contained more stars in low galactic latitudes than the southern visual Durchmusterungs and fewer in high latitudes. R. T. A. Innes, who had come to the Cape Observatory at Gill's invitation at the beginning of 1896 to take the post of secretary, assisted de Sitter in these observations and so began the friendship between de Sitter and Innes which was later to bear fruit in the scheme of co-operation between the Leiden Observatory and the Union Observatory, Johannesburg.

Whilst de Sitter was at the Cape, Gill suggested to him that he should take up the reduction and discussion of a series of heliometer observations of Jupiter's satellites which had been made by Gill and Finlay in 1891, as an appropriate subject for his dissertation for the doctor's degree at the University of Groningen. These observations had been made as the result of a discussion some years previously between Gill and J. C. Adams, on

the subject of the kind of observations required to improve the tables of the motions of Jupiter's satellites. Adams was at that time engaged on the correction of Damoiseau's tables of the satellites. As a result of the discussion, Gill planned a series of accurate heliometer observations of position angles and distances of the satellites with respect to each other. But pressure of other work delayed first the observations and then their reduction. De Sitter took up the subject with much interest ; as a result of his discussion, strongly determined corrections of considerable amount to the inclinations and nodes of all the satellites and an accurate determination of the mass of Jupiter were obtained.

De Sitter left the Cape in 1899 December, but the subject of Jupiter's satellites continued to engage his interest for the next thirty years. It was one in which his mathematical training could have full scope, but one which could not have been successfully attacked except by a person who, like de Sitter, had a critical appreciation of the value and limitations of observations. The training at the Cape under Gill, who possessed in a very high measure an insight into the value of observations and the errors to which they are liable, was doubtless in large measure responsible for the development in de Sitter of the same insight.

At de Sitter's request, several series of photographic observations of the satellites of Jupiter were obtained at Greenwich, the Cape, Johannesburg, Leiden and Pulkova. These were reduced under de Sitter's supervision and critically discussed by him. In the mathematical investigation he used an intermediary orbit, in which the eccentricities were taken as zero and the great inequalities appeared as equations of the centre. For the three inner satellites this gave a better approximation to the true motion than the undisturbed Keplerian motion. Old observations of eclipses of the satellites, extending back to the year 1668, were also reduced and discussed. It was not until 1929 that de Sitter was able to publish the definitive values of the orbital elements and masses of the four satellites. The theoretical discussion was published in 3 parts, in 1918, 1919 and 1925 ; the second part was carried out by Dr. A. J. Leckie, under de Sitter's general direction. Tables of the motions of the satellites, based on the new theory, have not yet been published, but much preparatory work has been carried out and it is to be hoped that it will be possible for one of de Sitter's collaborators to complete the reduction to the form of tables.

Meanwhile, on the retirement of Professor H. G. v. d. Sande Bakhuyzen, his office was divided into two parts. The one, the Directorship of the Leiden Observatory with a Professorship of Practical Astronomy, was filled by E. F. v. d. Sande Bakhuyzen. The other, the Chair of Astronomy in the Leiden Observatory, was filled by de Sitter in 1908. On the death of E. F. v. d. Sande Bakhuyzen in 1918, de Sitter was appointed also Director of the Leiden Observatory. This old-established institution, whose tercentenary was recently celebrated, had ceased to be an institution of importance. The Government had decided on a complete reorganisation and considerable enlargement. De Sitter and Kapteyn together drew up plans for a reorganisation along the lines of modern developments. The obser-

vatory had hitherto been concerned mainly with fundamental observations ; astrophysical and theoretical departments were now formed, the fundamental department was reorganised and the observatory became one of the most important in Europe. In connection with the fundamental work, de Sitter planned a programme for the determination of fundamental declinations based on observations of azimuth from a station near the equator and from two stations north and south of the equator, in a latitude of about 30°. A special instrument, largely of de Sitter's design, was constructed for these observations by Messrs. Cooke, Troughton & Simms, Ltd., of York, but the completion of the programme of observations was delayed by financial difficulties and at the present time only one series of observations, at a station in Kenya near the equator, has been obtained.

The reorganisation of the observatory and the considerable amount of administrative work entailed in its direction made considerable demands on de Sitter's time. Yet papers of importance on various topics continued to appear with remarkable regularity. This is the more surprising as he was far from robust, and he suffered from a serious illness for some years which for a time necessitated his residence in Switzerland. In 1915 appeared the first of a series of papers on the co-ordination of astronomical constants. Newcomb's *Fundamental Constants of Astronomy* was published in 1895, and the large mass of observations accumulated since that date permits of various improvements being made. Nobody was better fitted than de Sitter for undertaking such a revision. The first paper was concerned mainly with the figure and composition of the Earth ; in 1927 a second paper appeared dealing with other constants such as precession, nutation, solar parallax, lunar parallax, mass of the Moon. A new investigation in continuance of this work had almost been completed at the time of his death.

An important series of investigations by de Sitter was concerned with the theory of relativity. In 1911 he contributed to the *Monthly Notices* a paper dealing with the small deviations in the motions of the Moon and planets from Newtonian dynamics to be expected on the basis of the restricted principle of relativity. Shortly after the appearance of Einstein's paper on the generalised theory, de Sitter in 1916–17 communicated a series of three papers to the Royal Astronomical Society, giving not only a complete exposition of the mathematical theory but also a detailed examination of its astronomical consequences. The third of these papers contains his most important contribution to the subject, for in it what is now generally called the "de Sitter universe" was put forward as an alternative to the "Einstein universe." These papers appeared in the *Monthly Notices* at a time when, owing to war conditions, Einstein's paper was practically unobtainable. Their appearance not only stimulated the study of the new theory in this country but also considerably influenced the form in which the theory has been presented. The British eclipse expeditions of 1919, which provided the first evidence in support of Einstein's conclusions as to the amount of deviation of rays of light in passing near the Sun, would probably not have been sent out had de Sitter's papers not appeared. The confirmation of the deflection, provided by the data derived from these expeditions, did much

to secure general acceptance of the theory at a time when many men of science had hesitated to accept it. More recently, after it had been proved that the universe represented by the static solution of the theory was unstable, de Sitter returned again to the theory and examined mathematically the various types of non-static solution possible ; he showed that there were three types of solution. These he termed the expanding universe of the first kind, in which the radius decreases to a small value and then expansion to an infinite radius follows ; the expanding universe of the second kind, in which there is continuous expansion from an initial finite radius ; and the oscillating universe in which the radius alternately increases and decreases.

Another subject which attracted de Sitter's attention was the variability of the Earth's rotation. He was led to the consideration of this matter as a result of his discussion of the early observations of the eclipses of Jupiter's satellites. These he used as a check on the uniformity of astronomical time, as measured by the rotation of the Earth. His discussion was made with characteristic thoroughness and left no doubt as to the reality of the variations in the rate of rotation, and that these variations may occur with considerable abruptness. He concluded that all the observed phenomena could be explained by supposing that there is a varying tidal friction which influences the rotation of the Earth and also the motion of the Moon and that in addition there are comparatively sudden changes in the moment of inertia of the Earth, which affect the Earth's rotation only.

Mention has been made of the co-operation between the Union and Leiden Observatories. The observing conditions at Leiden are very poor, whereas at the Union Observatory, Johannesburg, the amount of clear sky is so great that the instruments cannot be operated to their full efficiency by the limited staff. Through his friendship with Innes, de Sitter came to an arrangement by which the Leiden Observatory stations an observer permanently in Johannesburg to use one of the telescopes. This co-operation has proved very fruitful in results. Further developments were planned ; through a large gift from the Rockefeller Foundation a powerful instrument was obtained, which is to be erected by the Leiden Observatory at the Union Observatory, Johannesburg. This instrument, constructed by Messrs. Sir Howard Grubb, Parsons & Co., was almost completed at the time of de Sitter's death.

The profound effect on de Sitter's life of the chance meeting with Gill has been emphasised. De Sitter's visit to the Cape had a further result; it was there he first met the lady who became his wife. Their married life was singularly happy; they had two sons and two daughters, all of whom are married. De Sitter's greatest joy was to have his children and his grandchildren around him in the charming home at the observatory.

De Sitter was a frequent visitor to England and his visits were always welcomed by his colleagues. He was a not infrequent visitor to the meetings of the British Association, and attended the two meetings of the Association in South Africa in 1905 and 1929. He was elected an Associate of the Society in 1909 and was awarded its Gold Medal in 1931. He was the

recipient of the Watson Gold Medal of the National Academy of Sciences, Washington, in 1929, and of the Bruce Gold Medal of the Astronomical Society of the Pacific in 1931. In the period 1925–28 he was President of the International Astronomical Union. He died on November 19 last from pneumonia at the comparatively early age of sixty-two years, and at a time when there was no apparent diminution in his output of work. The loss, not only to his observatory but to the whole world of astronomy, is severe.

H. S. J.

PROCEEDINGS OF OBSERVATORIES

The following reports of the proceedings of observatories during the past year have been received from the respective Directors, who are alone responsible for them.

Royal Observatory, Greenwich
(*Director, Dr. H. Spencer Jones, F.R.S., Astronomer Royal*)

Transit Circle.—The work on the zone catalogue of stars between the equator and declination $+24^\circ$ has been continued. The number of transits observed during the year 1934 was 10,581, including 147 of the Sun and 104 of the Moon. The reductions are in hand.

The printing of the *Second Greenwich Catalogue* for 1925 is now complete, and this Catalogue will soon be available. It is based on observations extending over the period 1922 January to 1930 December, and contains places and revised proper motions for 1950 stars in Boss's Catalogue and for all stars brighter than $8^m.0$ between declinations $+32^\circ$ and $+64^\circ$.

Cookson Floating Zenith Telescope.—The number of plates taken for the determination of the variation of latitude were :—

January—29	May—24	September—32
February—8	June—11	October—20
March—13	July—34	November—4
April—17	August—27	December—14

In addition to these, five plates were taken for the determination of scale.

Preliminary values for 1933 were published in the *Monthly Notices* for 1934 March.

28-*inch Refractor.*—202 measures of double stars were secured. Arranged according to separation they are :—

Under $0''.5$	43	observations
$0''.5 - 1''.0$	83	,,
$1''.0 - 2''.0$	68	,,
Greater than $2''.0$	8	,,

26-*inch Refractor.*—The number of plates obtained suitable for the determination of stellar parallax was 1293. 823 plates were measured and 33 parallaxes completed. The parallaxes of 30 stars were published in the *Monthly Notices* for November.

Observations of Stellar Parallax, vol. ii, was published during the year. This volume contains the parallaxes of 251 stars, and its introduction gives, *inter alia*, discussions of the distribution of the stars according to parallax, and of their absolute magnitudes when grouped according to spectral type and proper motion.

30-*inch Reflector*.—The discussion has been completed of the series of absolute observations, obtained in the summer of 1933, for the purpose of re-determining the zero point of the Greenwich standard system of colour temperatures. The results were published in the *Monthly Notices* for 1934 April. They confirm the high colour temperature of the zero point obtained by a previous series of observations. The combined results of the two determinations give a colour temperature of 18,000° K. for the zero point which is defined as the mean of 9 stars of spectral type A0.

Yapp 36-*inch Reflector*.—The necessary adjustments to the telescope and slitless spectrograph having been made, the instrument was brought into use on April 20. It is being devoted for the present to the colour temperature work hitherto carried on with the 30-inch reflector. The performance of the instrument is highly satisfactory and, together with its convenience in use, will greatly facilitate the work. Attention is being concentrated on stars of types O, B and A, and their gradients are being determined by comparison with the Greenwich standard stars. Up to the end of the year, 245 comparisons of 72 stars with standard stars were secured. About half of the plates have been measured and reduced.

In addition, a series of plates have been exposed on Nova Herculis. All of these have been calibrated for photometry and whenever possible a comparison star was photographed at approximately the same altitude as the Nova. These plates will provide material for studies of the general behaviour of the spectral lines and of the distribution of energy throughout the spectrum.

A contract for the construction of a slit spectrograph has been placed with Messrs. Adam Hilger, Ltd. This spectrograph will have two prism systems, viz. one prism and three prisms. All the optical parts will be constructed of ultra-violet glass.

Astrographic Equatorial.—(*a*) Suspected Nova in Geminorum (Morgenroth). Three plates of the field were obtained on November 23 and December 5. On the latter date a star of about 13·5 photographic magnitude was identified near the place indicated. On the Franklin-Adams Chart it appears to be about magnitude 15.

(*b*) Nova Herculis. Subsequent to the discovery on December 13, fourteen photographs were obtained with a coarse diffraction grating for the determination of the photographic magnitude of the Nova.

Photoheliograph.—The Sun was photographed on 270 days at Greenwich and on 351 days at the Cape. There are 5 days not covered by either series, but plates for these dates are available at Kodaikanal.

For 1934, the mean daily area of sunspots, corrected for foreshortening, was approximately 110 millionths of the Sun's hemisphere. The published values for the years 1924–33 are 276, 830, 1262, 1058, 1390, 1242, 516, 275, 163 and 88 millionths respectively. The usual summary of positions and areas for the year 1933 was published in the supplementary number of the *Monthly Notices* for 1934. Sunspot numbers have been supplied quarterly to Zürich.

The recurrent sunspots during the cycle 1924–33 have been used to

determine the Sun's rotation period as was done previously at Greenwich in 1924 from data for the four preceding cycles, 1878–1923. The value of ξ, the daily sidereal motion, expressed in the usual form $a - b \sin^2 \phi$, is $14^\circ{\cdot}37 - 3^\circ{\cdot}0 \sin^2 \phi$ for the epoch 1924–33. The corresponding values of a for the four preceding cycles, 1878 to 1923, are respectively $14^\circ{\cdot}36$, $14^\circ{\cdot}39$, $14^\circ{\cdot}39$, $14^\circ{\cdot}39$, and the values of b are $2^\circ{\cdot}5$, $3^\circ{\cdot}0$, $2^\circ{\cdot}8$ and $2^\circ{\cdot}6$ respectively.

Considerable progress has been made in copying on bromide paper the early part (1874–1903) of the series of solar negatives collected at Greenwich.

Spectrohelioscope.—Observations were made on 200 days and include measures of radial velocity of 136 dark $H\alpha$ flocculi associated with sunspots and 412 measures of dark flocculi not associated with sunspots ; 181 measures were also made on areas of bright flocculi. During the year, five bright eruptions of minor extent were observed in $H\alpha$ on the disc and reported to Meudon.

An analysis of the measures of radial velocities for the years 1930–33 is given in *M.N.*, **94**, 472, 1934. In particular, the frequency distribution of measured radial velocities of dark $H\alpha$ flocculi associated with sunspots shows a peak at velocities 20 to 40 km./sec. and is in general accordance with the distribution derived by Dr. S. Chandrasekhar from his theoretical researches on the Sun's chromosphere.

During last summer preliminary measures were made of the intensity of bright $H\alpha$ flocculi compared (by means of an optical wedge and an intermediary lamp-source) with the continuous spectrum about 4A away on each side of the centre of $H\alpha$ in the same part of the disc. Preliminary intensity measures of prominences visible in $H\alpha$ and also in $H\beta$ were also begun, but of necessity temporarily suspended during the adverse observing conditions of the last few months.

The four mirrors of the optical train of the spectrohelioscope have been coated with aluminium films by Messrs. Adam Hilger, Ltd. It had previously been necessary to re-silver the two cœlostat mirrors every two months. The aluminium coating has satisfactorily removed this trouble.

Measurement of Total Line Intensities in the Solar Spectrum.—Some exploratory work has been carried out with a linear thermo-couple by Messrs. Kipp & Zonen, and a Paschen galvanometer by the Cambridge Scientific Instrument Co.

Clocks and Time-Service.—Observations for clock correction were made with the small reversible transit "D" on 141 nights. The transit observations are recorded on a tape chronograph operated by a thermionic valve system. The free-pendulum clock, Shortt No. 11, has been used as standard sidereal clock throughout the year. Comparisons have been maintained between this clock and Shortt No. 3, except during the periods when the latter was undergoing overhaul and adjustment. The mean time free-pendulum Shortt No. 16 has controlled all mean time-signal distribution, including wireless time-signals from Rugby and B.B.C. stations, and the hourly telegraphic time-signals to the G.P.O. A mean time free-pendulum Shortt No. 49 has been purchased and is designed for the same

service as an alternative to No. 16. The master pendulum has been installed in a cellar adjoining that containing the sidereal master pendulums, the chamber being fitted with apparatus for close temperature control. It is proposed to remove the master pendulum No. 16 from the small room under the Shuckburgh Dome to the same cellar as No. 49.

Daily registration has been maintained of wireless time-signals from Rugby and Bordeaux and when possible from Nauen and Annapolis. A cathode-ray oscillograph apparatus, including a motor-driven cine camera and time base marker, has been set up in the wireless room for determination of the lag in recorded times of wireless time-signals.

Some preliminary observations were made with the apparatus in November, and the results are confirmatory of the values shown by the Duddell oscillograph in the previous year.

The International Longitude Programme, 1933.—The results of the time determinations in connection with this programme and the observed times of reception of various wireless time-signals have been communicated to the Bureau International de l'Heure, Paris, where the results obtained by the various co-operating observatories will be co-ordinated and discussed.

Observations of Eros.—The measurement of the plates taken in connection with the 1930–31 opposition is proceeding. The following series of plates have now been measured:—

(*a*) The Greenwich series of 113 plates taken for the purpose of obtaining positions of secondary comparison stars required for the reduction of photographs of Eros obtained with long focus instruments.
(*b*) The Cape series of 114 plates taken for the same purpose.
(*c*) The Greenwich series of 160 plates exposed on Eros with the 26-inch refractor.
(*d*) The Greenwich series of 204 plates exposed on Eros with the 13-inch astrographic telescope.
(*e*) The Radcliffe series of 52 plates exposed on Eros with the 24-inch refractor.
(*f*) The Melbourne series of 41 plates exposed on Eros with the 13-inch astrographic telescope.

The following series of plates have been received and are at present being measured:—

(*g*) The Cape series of 478 plates exposed on Eros with the Victoria Telescope; and
(*h*) The series of 60 plates exposed on Eros with the Yale photographic refractor at the Johannesburg Station.

The reductions are in hand. Plate-constants for series (*a*) and (*b*) have been computed and adopted, and the conversion of the measured co-ordinates of the secondary comparison stars on the series (*a*) plates to right ascension and declination has been commenced. For series (*d*) and (*f*) stars from Dr. Kopff's list are being used as reference stars and the standard co-ordinates of these have been computed. For the other series the fainter

secondary comparison stars will be used, and in the case of series (*g*) the computation of standard co-ordinates is in progress.

In addition, plates have been received from the Harvard Station at Bloemfontein and from the Sydney Observatory. These will be dealt with later.

Printing.—The volume, and separate parts, of *Greenwich Observations* for 1932, have been distributed. Volume ii of *Observations of Stellar Parallax* has been received and is awaiting distribution. The final proofs of *Greenwich Observations* for 1933 and the *Second Greenwich Catalogue of Stars* for 1925·0 have been passed.

New Reversible Transit Circle.—This instrument has been completed by Messrs. Cooke, Troughton & Simms, and is undergoing final tests at the works in York preparatory to erection at Greenwich. The housing for the instrument, constructed by the Cleveland Bridge Co., has been erected. It is semi-cylindrical in shape, the axis of the cylinder coinciding with that of the transit circle. The internal diameter of the cylinder is 30 feet. Two shutters can be opened to give an aperture of 8 feet width along the meridian. The housing is covered externally with copper sheeting and adequate thermal insulation is secured by a lining of compressed cork slabs, 3 inches thick. The motor and gear for opening and closing the shutters have been installed.

Miscellaneous.—Mr. H. H. Furner retired on 1934 November 25.

Dr. E. Johannson of Upsala and M. and Mme. Brisse of the Paris Observatory studied some of the work of the Observatory during the year.

The Annual Visitation was held on 1934 June 2. On that occasion the 36-inch reflecting telescope, presented with its accessories by Mr. W. Johnston Yapp, was formally accepted by the First Lord of the Admiralty.

Royal Observatory, Edinburgh

(*Director, Professor R. A. Sampson, F.R.S., Astronomer Royal for Scotland*)

In the East Dome the Great Reflector has been used without change of plan, in conjunction with the spectrograph in its 2-prism form, and the intermediate camera, to accumulate spectra of a variety of stars, especially variables. It has worked well, no fault having to be recorded. The great mirror was improved by resilvering in the course of the year. The Leroy pendulette which controls the driving stopped recently. It was dismounted and cleaned and replaced. It is now going normally.

The discovery of Nova Herculis (1934) has diverted the general plan, though without any change in method. Using both evening and morning hours when the star was reasonably high, many complete spectra have been obtained, running from above [C] to below [K], with iron-arc comparison. Preparations are in progress for the time when the star falls in magnitude to change over without loss of time to a different form of the spectrograph, the apparatus for which is here already.

A good deal of time has been spent upon the theoretical question of measuring and interpreting the intensity of lines of spectra.

In the West Dome the plan is also running normally. All serious work is done with the camera—aperture 10 inches, focal length 60 inches—the stellar images given by the visual 15-inch telescope being still very poor. The blink microscope for examining plates is completed and in use. It proves to be not only the sole practicable method of comparing such a large mass of material, but reasonably convenient in use. The first pair of plates compared with the machine revealed three of the four known variables in the region (the fourth having a range of only 0·1 mag.) and also four new variables. Similar results are being obtained in other regions, in one of which a known large proper motion was noticed, although the interval between plates was only one year.

So far the provision in the West Dome has played a minor part in investigating the Nova.

The time-keeping system has also worked normally. No further trouble has been experienced in the leak in the case of Shortt No. 4. Shortt No. 0 also showed a leak. The clock was taken down, but the case, upon examination, was passed as satisfactory. The clock was replaced, and attention given to the tap and other places of communication with the outside air. It is now showing no sign of fault. The rates of all four independent clocks are very steady.

Attempts were made to devise and construct a mechanical drive for the Bamberg reversing transit. It was suspected that the hand drive used in the World Longitude Scheme was responsible for some error. The various attempts have been abandoned as unsuccessful. In the course of making them some variations were made in the hand drive, which it is intended to pursue.

Royal Observatory, Cape of Good Hope
(*Director, Dr. J. Jackson, H.M. Astronomer*)

Reversible Transit-Circle.—The observation of stars down to magnitude 7·5 in the zone from the equator to declination −30° was continued. It is intended that each of the 7415 stars should be observed two or three times in each position of the instrument. The programme commenced in 1932 is now about half completed. The total number of transits observed during the year was 12,571, including 209 of the Sun, 91 of Mercury, 144 of Venus, and 33 of Vesta. About three bright stars from a list of 297 are observed daily when possible between 9 and 11 a.m. About two-thirds of these are clock stars, and all are in an equatorial belt. In 1934 the observations of such stars numbered 467.

The instrument was reversed 19 times during the year. This is normally done after eight determinations of azimuth, a determination of azimuth depending on the observation of two stars, one above pole and the other below.

All the observations for stars from −30° to the south pole observed in the years 1925 to 1932 have been entered in the ledgers and are being reduced to 1925·0. The reduction of the Zodiacal stars is being pushed

ahead as the observations are wanted at Washington for inclusion in the new catalogue of Zodiacal Stars.

Eight-inch Transit-Circle.—This instrument was used for the determination of the positions of stars required for the reduction of plates taken with the wide-angle lens in the zone $-35°$ to $-40°$. The number of transits observed numbered 2561, including 94 of azimuth stars.

The observations for the zone $-30°$ to $-35°$, completed in 1933, have been completely ledgered and reduced to 1950·0—the epoch to which all the zone observations will be reduced.

Zone Observations.—The work of photographing the zone $-30°$ to $-35°$ was completed in 1933. Seven plates have been measured, and now that the measurement of the Eros plates is completed, this work will be pushed forward. For purposes of comparison the stars in the Cordoba B Catalogue between $-30°$ and $-32°$ and the stars in Cordoba C $-32°$ to $-37°$ are being reduced to the epoch 1950·0 with Newcomb's precession. There are about 19,000 stars in all, and the work is nearly half finished. The approximate co-ordinates of the centres of all the plates have been measured, and the standard co-ordinates of about 1000 stars on each of two overlapping plates have been computed.

As the form of the out-of-focus images was unsatisfactory after the return of the lens from the makers it has been sent back a second time. The zone $-35°$ to $-40°$ will be photographed as soon as possible, so that the epoch of the plates may correspond to the mean epoch of the meridian observations.

Victoria Telescope.—The instrument was in use on 265 nights in connection with the work on stellar parallax. 2641 plates were obtained for the regular programme, 11 for proper motion, and 138 preliminary plates for the selection of comparison stars in new regions and ultimate use in the determination of proper motion. A sixth list of parallaxes, bringing the total to 600, was published in *M.N.*, 95, 70, 1934. By the end of the year another 20 parallaxes had been determined.

The copy for press of the detailed results for the first 216 parallax determinations was completed, and the proofs for the tabular matter have been corrected and passed for press.

Heliometer.—The following observations of major planets were obtained near the times of opposition :—

Jupiter	48	observations	of	distance	on	5	nights.
,,	24	,,	,,	position angle	,,	2	,,
Saturn	80	,,	,,	distance	,,	6	,,
Uranus	80	,,	,,	,,	,,	6	,,
Neptune	40	,,	,,	,,	,,	5	,,
,,	40	,,	,,	position angle	,,	5	,,

The proof sheets for the heliometer observations made in the years 1922 to 1931 were corrected, and the volume was printed and issued.

Occultations.—The following occultations of stars by the Moon were observed, 26 disappearances at the dark limb, 16 reappearances at the dark

limb, and 1 at the bright limb. Three occultations of the star 17 G Libræ have been observed to take place in two stages, although this star has not been recorded as double.

Photoheliograph.—702 photographs of the Sun were secured on 351 days. In addition 30 plates were taken for the determination of zero position angle. Visual observations for this purpose were made weekly.

Original negatives up to 1934 October 22 and duplicates up to 1934 November 12 have been sent to Greenwich for measurement and preservation.

Proper Motion of Stars in the Cape Astrographic Zone $-40°$ to $-52°$.—This work is nearing completion. The corrections depending on position on the plate and the reduction from relative to absolute have been applied. The latter include the effects not only of solar motion but also of galactic rotation. The copy for press of the proper motions for the 20,843 stars in the Zone Catalogue has been completed and checked and the discussion of the results has been commenced. In addition to these the proper motions of 20,554 fainter stars have been determined, including all those of magnitude 9·1 to 9·5 in the C.P.D. As the centre of the zone ranges in galactic latitude from $-72°$ to $+16°$, the distribution in right ascension of these stars is very unequal, the numbers for successive intervals of 3 hours being 823, 1182, 3447, 4159, 3126, 5030, 1613 and 1174. The writing out of the copy for press for these stars has been started but will take several months. The following data will be given for each star. R.A. and Dec. for 1900 with precession and secular variation, epoch, number of observations, proper motion, number in C.P.D. or Astrographic Catalogue, photographic magnitude, and when available the spectral type from the Henry Draper Catalogue.

Opposition of Eros 1931.—The Astronomer Royal has very kindly consented to have the plates taken with the Victoria Telescope measured at Greenwich. This has allowed us to concentrate on the plates taken with the Astrographic Telescope. All the serviceable plates, 532 in number, taken with this instrument have now been measured in right ascension. 376 plates, including all those taken near the meridian, have been measured in declination.

On account of the importance of tilt on the final results, the residual tilt was determined by a comparison of pairs of plates of the same regions taken with the instrument east and west of the pier. These plates were selected from those available showing large numbers of stars and distributed throughout the period of observation. The tilt was found to be constant and the necessary corrections have been applied. All the measures have been reduced and compared with the ephemeris. The residuals indicate a positive correction to the adopted solar parallax of $8''·80$, but its magnitude will probably be considerably influenced by corrections to the adopted places of the reference stars, still to be applied.

Time-Service.—The sidereal clock Shortt 10 ran well throughout the year except for a stoppage of the slave clock on July 10, when Riefler 152 was adopted as standard for a few days. There were intermittent failures of Shortt 27, which is the standard mean time clock, but it is hoped that this

has now been remedied, the trouble apparently being due to friction at the pivot of the resetting electromagnet of the master pendulum.

The Belin emitter, which emits time-signals on a modified ONOGO system from Slangkop at 21^h G.C.T. behaved much better than in the previous year. There were 15 failures, whole or partial, of which 5 were due to faults outside the observatory. There were no failures of the time-signals sent out by the African Broadcasting Station and controlled by the Molyneux mean time clock. There were 6 failures of the time-gun on Signal Hill—all due to faults outside the observatory. The use of the time-ball at Table Bay was discontinued from February 1.

To save time the number of time-signals which are received has been reduced. Bordeaux 8^h is taken three days a week, and Rugby 10^h on the intermediate days.

Miscellaneous.—Dr. E. C. Bullard from the Department of Geodesy, Cambridge, made gravity observations in the basement of the Victoria Observatory on April 22. Mr. R. H. Mansfield from the Carnegie Institution at Washington made magnetic observations in the grounds of the observatory in June.

The year has been exceptionally fine for observing and a very large number of observations have been secured. On only 14 days were no photographs of the Sun obtained. In the previous best year, 1930, the Sun was missed on 22 days.

Armagh Observatory
(*Director, Rev. W. F. A. Ellison*)

Planetary work with the 6-inch and 10-inch equatorials was carried on as occasion served. The 6-inch was utilised as usual for solar and lunar observation, and on occasions for demonstration of objects to parties of visitors. The 18-inch reflector was used for stellar spectra, so far as the very inadequate spectroscopic equipment available allowed. The remarkable Nova in Hercules, discovered on December 13 in the early morning, was observed here the following evening, and has been followed with the spectroscope since. The region between Vega and the head of Draco happened to be under particular scrutiny on the evening of the 12th, and it is certain that there was nothing unusual there. A strange star in the position of the Nova could hardly have failed to attract attention.

Cambridge Observatory
(*Director, Sir A. S. Eddington, F.R.S.*)

The Sheepshanks telescope has been used for the photo-electric study of variable stars throughout the first ten months. Since November 6 it has been out of action, since the counter-cell was required by the instrument-makers for fitting the cell of the new photographic object-glass.

The following variables have been observed, the number of nights on which measures of magnitude were obtained being given in brackets :—

β Lyræ (51), *u* Herculis (34), Algol (31), δ Cephei (25), *b* Persei (20), β Aurigæ (18), ϕ Persei (17), λ Tauri (15), ζ Aurigæ (10), 1 H. Cassiopeiæ (10). The following were also observed occasionally :—α Cassiopeiæ, ρ Cassiopeiæ, ζ Geminorum, η Geminorum, *o* Herculis. The observations of ζ Aurigæ, which were made in conjunction with Dr. Beer's spectroscopic observations at the Solar Physics Observatory, have been communicated to the Society (*M.N.*, 95, 31). A new method of determining the atmospheric extinction factor used in reducing the observations has been introduced by Dr. Smart (*M.N.*, 94, 839).

No photographs have been taken, but four fields of photographic proper motions have been measured.

When Nova Herculis appeared a calcite prismatic spectrograph was mounted on the Thorrowgood telescope, and a number of plates were secured.

Three research students have been working under the supervision of Dr. Smart. Mr. C. G. Pendse's investigation of the stability of Saturn's rings is being published by the Royal Society. Mr. R. A. Lyttleton has completed an investigation of the perturbations of the Algol system by the distant third component (*M.N.*, 95, 42).

Theoretical papers by Dr. Smart on "Some Theorems in the Statistical Treatment of Stellar Motions," and by the Director on the "Density of Interstellar Calcium and Sodium," have been published in the *Monthly Notices*.

Solar Physics Observatory, Cambridge University
(*Director, Professor F. J. M. Stratton*)

The staff remains unchanged. Professor C. T. R. Wilson has continued the supervision of work on meteorological physics. With Mr. J. G. Wilson he has been testing a novel type of expansion chamber likely to be especially useful for cosmic ray work. Mr. E. G. Williams and Mr. J. A. Edgar, Isaac Newton students, and Mr. A. D. Thackeray, Sheepshanks Exhibitioner (now a Commonwealth Fund Fellow) have been working at a number of stellar and solar problems during part of the year. Dr. A. Beer has been engaged in work on spectroscopic binaries and on several special stars. Dr. A. K. Das of the Indian Meteorological Service has been working on cosmic radiation and solar physics. Work on the ionosphere has been continued by Mr. J. A. Ratcliffe and members of the Cavendish Laboratory.

Buildings and Instruments.—The Hills siderostat has been fitted with a synchronous motor for an electric drive and with electric slow-motion controls worked from the laboratory. It has been used to feed the 21-foot Rowland grating for work on the solar spectrum. Its 12-inch mirror has been coated with aluminium by the Metropolitan-Vickers Electrical Company, as have also a number of smaller mirrors and one speculum grating. The latter has shown an average improvement of 50 per cent. in its reflectivity, the amount varying between the different orders and being in general more marked for shorter wave-lengths.

The 12-inch Cooke lens of the spectroheliograph has been cleaned of internal growths by Messrs. Cooke, and the 8 quartz half-prisms of the Hills spectrograph have been refigured by Messrs. Hilger, and the halves placed in optical contact. These prisms have been used in the construction of a monochromator for use with the Rowland grating and the McClean solar spectrograph. A constant temperature case and thermostat have been fitted to the prism end of the latter spectrograph.

The Newall dome has been repainted inside and out with aluminium paint. The storage batteries for the 100-volt direct current installation have had to be replaced after 20 years' use.

Solar Work.—During 1934 spectroheliograms of the Sun's disc in K_{232} light were secured on 63 days and of the limb on 55 days ; in $H\alpha$ light the disc was photographed on 12 days and the limb on 10 days. On most days when observations were possible the clear intervals have been too short to allow of the full programme for both *K* and $H\alpha$ plates. Improvements have been made to the mounting of the rotating prisms of the spectrohelioscope, and numerous observations have been made of prominences at the limb and dark filaments on the disc. The general activity of the Sun has been low and no violent eruptions have been observed.

A study of the total radiation from sunspots and surrounding faculæ has been commenced. The measuring apparatus, which consists of a Moll vacuum thermo-couple is used in connection with the Cooke 60-foot lens of the McClean solar installation. Equilibrium is reached within 0·5 seconds : the galvanometer deflections are recorded photographically on a revolving drum. Records have been obtained of a number of sunspots ; the drop of radiation as we pass from the normal disc to the umbra of a spot is in accord with results obtained elsewhere.

Stellar Work.—203 spectrograms were obtained on 95 nights with the Newall telescope. Preliminary work on the stellar rotation programme was continued, the plates being sent to Professor Carroll, Aberdeen University, for reduction. A programme of selected stars for this work has been agreed with Professor Struve of Yerkes Observatory, the methods and results to be checked from two independent sets of plates. Spectrophotometric work has been continued in the green, yellow and red regions of a number of stars, the *D* lines of *Na*, the *b* triplet of *Mg* and lines of *He* and *H* being specially studied. Special stars examined include δ Cephei, β Lyræ, ζ Aurigæ, α Andromedæ, and in the last fortnight of the year Nova Herculis 1934. The Huggins telescope has been used also on the last two stars ; also for the Nova the calcite prismatic camera has been mounted on the Thorrowgood telescope giving spectra from $H\alpha$ to 3000 A.

With the 3-foot Common reflector 53 photographs of elliptical nebulæ and 41 of standard starfields were obtained on 28 moonless nights. In deriving the total magnitudes of these nebulæ a systematic error has been found arising from under-exposure of the faint outer regions. A number of long exposures are being made to clear up this point.

Meteorological Physics.—Further records of the electric fields have been

obtained during disturbed weather conditions. Progress is being made in the reduction of the records obtained in the last few years.

Laboratory Work.—The spectrum of lines of *Fe* II appearing as polar lines in the arc has been measured from 2327 to 5000 A.; plates have been secured for the range 2150–8500 A.; 57 new multiplets have been found consisting of 32 doublets, 21 quartets (6 of these being high-level terms) and 4 high-level sextets; the total number of new levels is 157. Altogether 850 lines have been sorted into multiplets including nearly all the stronger lines in the spectrum. The number of lines measured is 2600. About 90 solar lines have been identified and classified below 5000 A., ranging from Rowland intensity 3 downwards.

The microphotometer has been in constant use. A new slow-motion adjustment has been obtained for it and other minor improvements have been made. Tests to find the error of positions on the plate as deduced from measurements made on the tracing show an average error of $2{\cdot}5\ \mu$, which compares satisfactorily with other instruments, and is probably approaching the limiting accuracy set by the bromide paper at a magnification of 50-fold.

Dunsink Observatory
(*Acting Director, Mr. Charles Martin, M.A.*)

The time service to Dublin has been continued as in previous years.

The observatory has been used mainly for teaching purposes, students being welcomed for instrumental and observational work.

Durham University Observatory
(*Observer, Mr. Frank Sargent*)

The observation of the assigned variable stars has been continued as before, 672 observations having been made. Certain planetary observations have also been recorded.

The meteorological work has been continued as hitherto.

The Milne-Shaw seismograms for the year have been analysed and the results forwarded to the International Bureau at Oxford.

The joint potential-gradient and earth-air current equipment are now in working order. Continuous records are being obtained and studied.

The Observatory Library has been catalogued and re-arranged.

Imperial College Observatory
(*Director, Assistant-Professor H. Dingle*)

Work in the observatory has been restricted, as usual, to the instruction of students. Many spectroscopic researches have been conducted in the laboratory, and the results of those which have been completed have been published through the usual channels. Among the more directly astronomical papers which have been published since the last report are

Dr. Dingle's account of the eclipse expedition to Montreal, 1932, and a short paper arising therefrom, dealing with the technique of observing the bright-line spectrum at the cusp of the partially eclipsed Sun ; an investigation of relativistic models of the universe, and an account, with wave-lengths and a map, of the iron-arc spectrum in the infra-red, by the same author ; interferometric determinations of the wave-lengths of the *H* and *K* lines in the vacuum arc and of silicon lines occurring in the spectra of early type stars, by Dr. C. V. Jackson ; an investigation of the contours of the potassium resonance lines in absorption, by Dr. J. F. Heard ; and a study of the solar limb effect, by Mr. A. Hunter.

The laboratory has suffered a great loss through the retirement of Professor Fowler in October. He is happily still available for advice and will, it is hoped, be a frequent visitor. He has been elected Emeritus Professor of Astrophysics at the College. Dr. W. Jevons, who several years ago was a demonstrator in the Astrophysics Department, has now joined the research staff. He has brought with him a quartz Littrow spectrograph and a concave grating with a modified Eagle mounting.

Liverpool Observatory and Tidal Institute

(*Director, Professor J. Proudman* ; *Associate-Director, Dr. A. T. Doodson*)

Tidal predictions of high and low water have been made for seventy places ; of hourly heights of water for one place ; and of times of slack water for three places. A year's tidal record from each of three places has been analysed.

Further research has been carried out on methods of tidal analysis and prediction and on the tidal bore of the River Trent ; much work has also been done on the dynamical theory of the tides. In co-operation with the Oceanography Department of the University of Liverpool, a study has been made of the variations of the temperature of the surface waters of the Irish Sea.

An electrically recording tide-gauge, with the recording element in the observatory, and a new Milne-Shaw seismograph, with an electrically driven recording drum, have been installed.

The regular meteorological and seismological services of observation and transmission of information, and the firing of the time-gun, have been continued.

University of London Observatory, Mill Hill, and University College Observatory

(*Director, Prof. L. N. G. Filon, C.B.E., F.R.S.* ; *Mr. C. C. L. Gregory, M.A., Wilson Observer*)

The 24-inch photographic refractor and 18-inch visual twin-telescope at the Radcliffe Observatory, Oxford, have been offered by the Radcliffe Trustees to the University of London. Arrangements are being made to store the instrument at the headquarters of the University until funds are

available for erecting it at Mill Hill. An additional strip of land behind the Observatory is being offered by the borough of Hendon for this purpose. It is proposed to use this telescope, when erected, for parallax work.

Wilson Reflector.—The Cassegrain and Newtonian mirrors of this instrument were successfully coated with aluminium during the summer by Metropolitan-Vickers. Owing to a breakdown in the apparatus, this put the telescope out of action for several months. Little work was done with this instrument on account of the indifferent health of the Wilson Observer during the Spring, and the very bad weather which was experienced during the Autumn. The telescope was used on 14 nights, and 5 plates were taken.

Rowland Grating Spectrograph and 8-inch Cœlostat Telescope.—During the first two months, experiments with photo-electric photometry were continued and were then abandoned for lack of an assistant. The equipment was then used, for the remainder of the year, for spectrographic work. Two of the three mirrors were coated with aluminium and a considerable improvement was obtained.

Fry 8-inch Refractor.—This instrument was used on 95 nights, and in addition 87 observations of sunspots were made. 19 plates were taken with the portrait-lens camera attached, mostly by Mr. Frank Robbins.

Measurement of Plates.—Miss White completed the measurement and computation of the proper motion plates for the Wilson Region in the neighbourhood of the cluster M13, and the results were published in *M.N.*, **94**, 783, 1934.

Occultations.—Observations of occultations were made on 26 nights, mostly with the Fry telescope, and the fourth list was published in *M.N.*, **94**, 88, 1934.

Miscellaneous.—All the volumes of the *Monthly Notices*, mentioned in the last annual report, have now been bound by Mr. Spratt, the Observatory mechanic.

Visitors.—There were 138 visitors during the year.

University College Observatory.—The work, which is mainly instructional, has been carried on as in previous years. During the summer, the dome of the 6-inch equatorial refractor* was dismantled. A new ring plate and set of wheels were made and installed by George Wailes, and the dome now works in a highly satisfactory manner. The 10-inch reflector by Calver is at present being re-conditioned in the College workshops.

Radcliffe Observatory, Oxford
(*Director, Dr. H. Knox-Shaw, Radcliffe Observer*)

The application of the Radcliffe Trustees for permission to transfer the Observatory to Pretoria came before the Court of Chancery in the summer and was approved in principle, but the judge directed that the scheme should be submitted to him at a later date for his final sanction as to its details. At the end of the year the legal formalities necessary before this further step

* This instrument appears to have been erroneously described as an 8-inch in last year's annual report.

could be taken had not been completed. In the second half of the year the energies of the staff were concentrated on preparations for the evacuation of the present site in June 1935.

The Radcliffe Catalogue of Proper Motions in the Selected Areas 1–115, containing results for over 32,000 stars down to a mean magnitude of 15·3 and with a mean probable error of ± 0″·0037, and embodying the main work of the observatory for the preceding 25 years, was published in August.

Two photographs were taken with the 24-inch of 61 Cygni and, at the request of Dr. Steavenson, two of the field of the nova of 1670. Nova Herculis (1934) was first observed on the morning of December 14, and estimates of its magnitude have been made on all possible occasions since.

University Observatory, Oxford
(Director, Professor H. H. Plaskett)

Staff.—While the permanent staff remains unchanged, the observatory has been fortunate in securing the services of Dr. H. Zanstra of Amsterdam, and Dr. P. ten Bruggencate of Greifswald as research associates for some two months each, and of Dr. R. V. Jones, the first holder of the Skynner Senior Studentship in Astronomy. Graduate research in astrophysics was also undertaken by Messrs. J. D. Babbitt, I. A. Getting, and T. L. Page.

Equipment.—The vertical Cassegrain-type solar telescope, with quartz mirrors to give a solar image of eight inches diameter, was completed by Grubb-Parsons in December. Its erection in the east tower of the observatory will be completed early in 1935. The optical parts of the large Littrow spectrograph were completed by Hilger in November, while work is proceeding on the mechanical parts by Casella & Co. as funds permit. The recording microphotometer has been subjected to a series of exhaustive tests (*M.N.*, **95**, 160), and after some minor adjustments by the makers has been in almost continuous use during the latter part of the year.

Astrophysics.—The observational determination of the surface brightness of the Sun as a function of wave-length and position was continued during the summer months. Dr. Jones, who proposes to make a study of the solar spectrum in the region λ 10,000 A. to 20,000 A., has experimented at the Clarendon Laboratory on the design and construction of bolometers, thermocouples, and the relays needed for this work.

In stellar physics Mr. Getting has completed an interesting study (*M.N.*, **95**, 139) of Milne's characteristic curves for a number of well-observed Cepheids, RV Tauri, and long-period variables. Dr. ten Bruggencate worked on the theory of the long-period variables, and on some interesting questions in stellar statistics. Mr. Babbitt is engaged in a study of some high dispersion spectra of Vega.

In nebular physics Dr. Zanstra completed an investigation (*M.N.*, **95**, 84) on the effects of radiation pressure in static and expanding nebulæ. Mr. Page is determining the energy distribution in the Balmer continuous spectrum of some typical planetary nebulæ, and thus hopes to make the first direct determination of electron temperatures in nebulæ.

Astrographic Catalogue.—The work on the Potsdam zones + 32° and + 33° is going forward very satisfactorily under Mr. Bellamy's direction. The observational work is 81 per cent. complete, while the measurement and reduction is 64 per cent. complete. Considerable assistance has been furnished by Dr. Wilfred Hall who has undertaken to provide for the measurement of the plates up to a certain maximum number.

Seismology.—A valuable introduction to the Seismological Summary has been provided by Mr. Hughes, giving an account of the methods used by him in the calculation of epicentres. For the earthquakes of the year 1930 both epicentres and station residuals have been determined, while the first three quarterly issues of the Summary for this year have been printed.

Norman Lockyer Observatory, Salcombe Hill, Sidmouth
(*Director, William J. S. Lockyer, M.A., Ph.D., Major (late R.A.F.)*)

The Kensington 9-inch prismatic camera has been in fairly regular use for photographing the spectra of selected Be-type stars and (later) of Nova Herculis (1934). The number of negatives secured during the year was 204. The Zeiss triplet lens attached to this instrument has been used occasionally for the photography of star regions during part of the time of the exposure of the spectra. Nine photographs have also been taken with the two fixed meteor cameras which are erected near the Kensington dome. The McClean 12-inch prismatic camera has been used for photographing the fainter B-type stars, and for investigating spectrum variables of the β Canis Majoris type. The spectrum of Nova Herculis has also been photographed with this instrument. The total number of spectra obtained was 65. Exposures with the Mond photographic equatorial were made on 3 nights, 10 plates being secured of various nebulæ and star regions.

The number of fine nights was 138, which is above the average annual number but not so good as the previous year, in which there were 148 fine nights. Successful observations were made on 112 nights, and 188 were completely overcast. The reduction of a number of the photographs taken with the several instruments was held up owing to the indisposition of the Director, who had to give up night work for several weeks.

Work has been continued on B-type stars which show bright hydrogen lines in their spectra; also on B-type stars in general, from the point of view of classification, peculiarities and spectroscopic parallaxes. Short-period spectrum variables of the β Canis Majoris type are also still under investigation. One new member of this group has been discovered and will be described in a forthcoming note.

The observatory suffered a great loss during the year by the death of Miss W. L. Lockyer who had acted for many years as its Honorary Assistant Secretary. Not only did she undertake a large amount of work, such as looking after the library, distributing and acknowledging publications, etc., but contributed many gifts in money and kind. In addition to several pieces of furniture and numerous astronomical books, she bequeathed £600 and a plot of land adjoining the observatory site.

The observatory is open to the public on Wednesday afternoons, and in addition was visited by large parties by special arrangement. The total number of visitors who attended during the year was 278.

The eighteenth annual general meeting of the Norman Lockyer Observatory Corporation was held in London on June 7.

Stonyhurst College Observatory
(*Director, Rev. J. P. Rowland, S.J., B.Sc.*)

The usual routine work of the observatory has been continued, and the meteorological, magnetic and seismological records have been maintained throughout the year, and the results forwarded to the official centres ; but owing to the continued shortage of staff it has not been possible to devote time to any special investigations.

Observations of the solar surface were obtained on 251 days, and these were supplemented by observations on 104 days at Zürich, kindly supplied by Professor Brunner, and on 2 days at Catania, leaving 8 days for which no statistics are available. Sunspot statistics have been sent quarterly to Professor Brunner for the preparation of "Sunspot Numbers" and International "Solar Character Figures," and daily "Magnetic Character" figures have been supplied quarterly to the International Meteorological Organisation at De Bilt.

With the onset of the new cycle, solar activity shows an increase on last year, the number of spotless days falling from 249 to 175, and the mean daily area of spots, in units 1/5000 of the disc, increasing from 0·41 to 0·58. The number of groups observed increased from 31 to 56, of which 39 were high latitude groups of the new cycle. Magnetic activity, on the other hand, shows a further decline, the mean daily ranges in declination and horizontal force being 12′·4 and 53·1γ respectively, as against 13′·4 and 58·1γ last year. The number of days on which the magnetic disturbance ranks as "greater" in our system of classification fell from 15 to 10, and there are again no days on which the disturbance is classed as "very great," or true magnetic storms.

During the year 117 earthquakes were recorded, of which the most notable was that which caused widespread destruction in Northern India on January 15.

In June and July the whole observatory was re-painted, both inside and out, and some woodwork which had become affected with dry-rot was renewed. During these renovations some inconvenience was inevitable, but the only interruption of records was that the seismograph was out of action for some days.

Dominion Observatory, Ottawa, Canada
(*Director, Mr. R. Meldrum Stewart*)

Meridian Work and Time-Service.—In completing the present part of the observing programme the meridian circle was used on 178 days, 1500

observations of right ascensions and declinations of stars, and 201 of the Sun, Moon and planets having been made. Observations for clock correction were made also with the remodelled Cooke transit on 25 nights. The system of synchronized clocks throughout the government buildings in the city continued to give satisfactory performance. The repair and rating of 204 clocks, chronometers, watches and other time machines was done for this and other departments of the government. New instruments in use include an improved personal equation machine and a high-speed drum chronograph reading to $0^{s}.002$. Wireless time-signals were received daily from Annapolis, Bordeaux, Nauen, Rugby, Monte Grande and Rio de Janeiro. Time-signals were sent out from the observatory by clock beats over the telephone, by telegraph, by radio broadcast over station CRCO and by short-wave transmission. Two systems of crystal clocks used by different departments for frequency standardization have been connected to the observatory by wire for direct comparison with the primary clocks. The computations of star positions and of positions of the Sun and planets have progressed fairly. The computations of international longitude have been completed.

Solar Physics.—During the year 250 solar spectrograms were secured recording one strip of spectrum from the centre of the solar disc together with two from midway points and four from limb points, with two strips of iodine absorption spectra. Over 30 photographs of the Sun were made on days when spots were present. Preparation for publication of the early solar rotation measurements, with elimination of the micrometer-oil errors of measurement, was continued. Two publications relating to the computation of heliographic positions and observed components of the solar rotation from any points on the solar disc by using tables or a graduated sphere and co-ordinate frame, are in the press. Most of the tree measurements made in connection with the investigation of the astronomical cycles in terrestrial phenomena in Canada have been prepared for distribution and eventual publication.

The 15-inch Equatorial.—The observational work during the first half of the year was restricted entirely to the photo-electric photometer. During the latter part of 1934 the spectrograph was again put into use. With the former some 129 observations were made, while the latter was used for testing some new plates, and also for obtaining spectra of Nova Herculis. Continued lack of staff was responsible for the smaller amount of work done than in former years. Among the stars investigated with the photometer were ν Eridani, ζ Geminorum and α Virginis. A number of microphotometer tracings were made from spectrograms of α Canum Venaticorum and some interesting variations in line intensities were noted. This study is being continued. Some work was done toward the completion of orbital elements of λ Andromedæ for the years 1924, 1925 and 1926. As in former years the telescope was made available to visitors every clear Saturday night. In connection with this, popular descriptions of celestial objects were prepared and printed in pamphlet form to be distributed to the public.

Photographic Photometry.—Observations were continued with the 6-inch

and 8-inch cameras on the Cepheid fields of the International programme. One hundred plates were obtained, some for comparison stars and some for the determination of light-curves. The fields of V Leo Min., V Comæ, RR Can. Ven., SW Bootis, TW Bootis, RT Scuti and VX Cass. were included in the former, and S Vulpeculæ, SV Vulpeculæ, X Vulpeculæ, RZ Cephei, Y Aurigæ, SU Persei and SZ Cass. were observed for light-curves. The plates of RZ Cephei and Y Aurigæ have been measured and reduced, but further plates are needed. Several objective prism plates of Nova Herculis were taken with the 25° prism and 8-inch camera.

Seismology.—During the year 399 earthquakes were recorded at the Ottawa station, and of this number 22 were reported to the Press and to Science Service, Washington, D.C. The date of occurrence and the area affected by each of the major earthquakes registered during the twelve-month period are as follows : March 12, Utah ; July 18, Panama ; July 18, New Hebrides ; July 21, Panama ; August 31, Baffin Bay ; November 30, Mexico ; December 30, Lower California ; December 31, Lower California. The short-period seismographs at Shawinigan Falls and Seven Falls and the auxiliary teleseismic stations at Saskatoon and Halifax were kept in operation throughout the year.

Terrestrial Magnetism.—During the past year field work, which was suspended for the years 1932 and 1933, was resumed. One of the two observers engaged occupied thirty-two stations in Alberta, British Columbia and Yukon territory. Of these twenty-four are exact repeat stations and the remainder, with the exception of one which represents a new locality, are in the vicinity of former stations. The other observer occupied fifteen stations, ten of which are new and five repeat, along the route followed by the Hudson's Bay Company's steamer *Nascopie* during the annual cruise along the Labrador coast, in Hudson Bay, Hudson Strait and eastern Arctic. At ten of these the usual data, declination, inclination and intensity, were determined ; but at five, owing to unfavourable weather conditions and the limited time available at the ports of call, only declinations were obtained. In addition to the field-work the usual redetermination of the magnetic elements and the intercomparisons of magnetic instruments were made at Ottawa.

Gravity.—Owing to restricted appropriations no pendulum field work has been carried on for the last four years. A general report on all gravity work in Canada has been completed and will be published in the near future.

Applied Geophysics.—In co-operation with the Geological Survey of Canada a torsion balance survey was made of the Malagash salt deposit in Nova Scotia. An area of about one square mile was covered in about four months with some 233 observations, making this the most complete survey of its kind so far undertaken in Canada. About 2 per cent. of the area surveyed is known to be underlain at a depth of 100 feet by salt. Over this ground large and characteristic gravitational effects were observed. It is believed the results will be useful in locating the limits of the deposit in respect to both areal extent and depth. A report on the geophysical surveys

of 1933 of the Grand Rapids siderite deposit in Northern Ontario was prepared and is ready for publication.

Publications.—Publications during the year included four numbers of the regular series of Publications of the Dominion Observatory, namely, Vol. x, Nos. 19 and 20, and Vol. xii, Nos. 1 and 2, *Bibliography of Seismology*. Other papers published elsewhere or issued in mimeographed form included the following: Theory and Operation of the Eötvös Torsion Balance; The Universe We Live In; Making the World Safe by Seismology; Surface-Reflected Waves of Shallow-Focus Earthquakes; Gravitational and Magnetometric Surveys of the Onakawana Lignite and Grand Rapids Siderite Deposits; The Isostatic Equilibrium of the Pacific Coast of Canada; Velocity of the Radio Signals in the 1926 International Longitude Observations; The Northern Belt of International Longitudes; Seismological Bulletin (monthly); Wireless Time-Signals (monthly); Saturday Evening Programme (quarterly).

Dominion Astrophysical Observatory, Victoria, B.C.
(*Acting-Director, Mr. W. E. Harper*)

Some changes occurred on the staff during 1934. Owing to ill-health Mr. S. N. Hill, computer, asked to be superannuated, which was granted, as from March 31. Dr. R. O. Redman, now of the Solar Physics Observatory, Cambridge University, was a seasonal assistant for somewhat less than two months in August and September. The Director, Dr. J. S. Plaskett, in September asked for retirement, as from 1935 January 31. This has been granted by the Department and he will be given the usual six months' retiring leave. He plans to spend some time in England.

The observing weather was about the average, as on 198 nights with 1227 hours 939 plates were secured. The sixteen-year average shows 202 nights with 1237 hours observing and 1344 plates. The telescope was out of commission on three or four possible nights this year by reason of the electric power being cut off through forest fires. A number of nights, or parts of nights, were devoted to photography at the prime focus, when 115 photographs of globular clusters were obtained. Of the remaining plates, 25 were secured with the new slitless camera and the remaining 798 with the usual cameras, mostly the single prism.

The Director and Dr. J. A. Pearce, in collaboration, have continued the discussion of the motions of the O to B5 stars. Taking account of galactic rotation, the mean parallaxes and absolute magnitudes of 13 type and magnitude groups were revised and the dispersion in absolute magnitude determined. Combination of the mean parallaxes as revised, with corresponding values of $\bar{r}A$, gave various values of A, the final mean value being $+0{\cdot}0155 \pm 0{\cdot}0009$ km./sec./parsec, while the final value of l_0 was determined as $324^\circ{\cdot}4 \pm 2^\circ{\cdot}4$. New precessional corrections were derived by Oort's method and applied to the proper motions, the solution then yielding values for $A = +0{\cdot}0133 \pm 0{\cdot}0027$ km./sec./parsec, and for $l_0 = 311^\circ{\cdot}5 \pm 9^\circ{\cdot}1$. The latter values are considered of less weight than those from the radial

velocities. With a rotational velocity at the Sun of 275 km./sec. the distance to the centre is 10,000 parsecs and the diameter 30,000 parsecs. Other interesting results may be found in *M.N.*, 94, 679. The full account is given in our *Publications*, Vol. v, No. 4, which is ready for the press.

Mr. W. E. Harper has continued to obtain spectra of some A-type stars on his list, where the velocities were somewhat uncertain. Considerable time has been spent also in securing plates for detecting any revisions necessary in the periods of binaries which he has already published. A paper containing the results for about 40 of these is nearly ready for the press. The spectroscopic orbit of 44 ι Bootis, a variable of the W Ursæ Majoris type, was determined. Both component spectra are approximately of type G2, but the measures indicate masses of about two to one. The component stars are smaller and denser than the Sun, ellipsoidal in shape and nearly in contact. Considerable time was spent measuring spectra with the micrometer engine with a view to obtaining wave-lengths of lines suitable for use in late-type stars.

As mentioned above, Dr. J. A. Pearce has collaborated with Dr. Plaskett in the work on the motions of the O to B5 stars. He has also continued his investigations on the orbital elements and masses of eclipsing variables and spectroscopic binaries. Twenty-eight additional spectrograms of TX Ursæ Majoris were obtained and the preliminary orbit, published in 1932, revised. Thirty-five additional spectrograms of Y Cygni were secured. These, with a few additional ones in the spring of 1935 and those obtained in the autumn of 1933, will enable a new determination of the orbit to be made. A number of early type eclipsing variables of magnitudes 8·0 to 9·5 are being observed.

Dr. C. S. Beals has observed stars with special reference to interstellar calcium and sodium lines, though some observations have been made of Wolf-Rayet stars, of P Cygni and of Nova Herculis. Earlier results have been confirmed that the sodium lines are stronger than the calcium. A study of the relative intensities of the sodium doublet has been made with the object of ascertaining more clearly the nature of the atomic mechanism responsible for absorption. Observations of the star P Cygni have tended to confirm the hypothesis previously advanced of the continuous ejection of atoms from the stellar surface, and evidence has been adduced that the surrounding envelope is stratified according to the ionization potentials of its constituent atoms. A paper in the November issue of *The Observatory* gives a short summary of this work. Experiments have been carried out in the laboratory with direct-current amplifiers with the object of eventually applying the results to stellar photometry.

Dr. F. S. Hogg has been securing spectra of Z Andromedæ, some planetary nebulæ and a number of stars of late types. He has studied the intensities of the lines and the general energy distribution in Z Andromedæ. A study has also been undertaken of the velocity distribution in planetary nebulæ and the energy distribution of their nuclei. He has experimented with the slitless spectrograph recently constructed and has used it on faint stars. The relative intensities of neutral and ionized calcium in late-type stars has been

investigated through the measurement of the contours of the lines in many such stars. About 100 direct photographs of globular clusters at the Newtonian focus have been obtained in collaboration with Dr. Helen B. Sawyer, who has discovered 100 new variables and determined the periods of 17 of them.

Dr. R. O. Redman, during his short stay at the observatory, was engaged in securing spectra of a few short-period eclipsing variables at times of eclipse in an endeavour to measure variations of line intensity from centre and limb of the primary star. Both slitless and slit spectrographs were used. Some of the plates were measured on the microphotometer.

Helwan Observatory, Ministry of Public Works, Egypt
(*Director, Dr. M. R. Madwar*)

Time-Service.—The time-service was maintained as usual, the error of the standard clock, Shortt No. 1, being determined from star transits. Rhythmic W/T signals were received daily from Bordeaux and Rugby during the morning.

The Shortt free pendulum stopped on August 4 owing to failure of the dry-cells battery to maintain the requisite current. It was not until September 27 that it ran satisfactorily again, the Riefler clock being used as a standard in the meanwhile. The reversible transit circle was used regularly throughout the year ; 42 transit observations were made.

Reynolds Reflector.—The reflector was used on 64 nights and 105 plates were taken during the year : 4 for focus, 4 on Nova Herculis (1934), 29 on the variable nebula N.G.C. 6729, 32 on various nebulæ in the zone 0° to 40° declination, 28 on the region of the South Galactic Pole and 9 for the purpose of investigating the Ross effect.

General.—The usual meteorological, magnetic, seismological and solar radiation observations were continued.

Publication.—Bulletin No. 37, on the Time Determination during the World Longitude Determinations in 1933, is now ready for distribution.

Visitors.—Since the beginning of July 1934 Mr. B. Svenonius (Lund) has been working at the observatory as a research student.

Nizamiah Observatory, Hyderabad
(*Director, Mr. T. P. Bhaskaran, M.A.*)

Observations with the astrographic telescope were continued on the same lines as in previous years and 126 plates were taken during the year, of which 35 plates with centres in dec. $+36°$ and $+37°$ were for purposes of the catalogue and the rest for the determination of proper motion in the zones $-17°$ and $-19°$. All the plates required for the catalogue of the section $+36°$ to $+39°$ have now been secured, and the work of measuring is expected to be completed early in 1935.

Steady progress has been maintained with the measurement and reduction of the photographs of Eros taken during the opposition of 1931, and

every effort is being made to have the measures ready for publication by the end of next year.

Vol. ix of the *Hyderabad Astrographic Catalogue* (containing measures of star images in zone $+39°$) has been distributed and arrangements are being made for the printing of Vol. x (zone $+38°$). The printing of Vol. viii, Part 1, dealing with the ledger of reference stars in zones $-17°$ to $-22°$, is well in hand and it is hoped the volume will be published early in 1935.

Regular observations of variable stars were continued with the 15-inch refractor. The working list contains 72 variables (long-period and irregular) mostly with faint minima; and 1263 estimates of visual brightness were obtained during the year.

Twenty-nine occultations of stars by the Moon—all disappearances except one—have been observed and some progress has been made with their reduction. Occasional observations have been made with the transit instrument for the determination of clock corrections.

The seismographs (two Milne-Shaw horizontal pendulums) have been operating satisfactorily and have registered 144 shocks during the year. No satisfactory record was obtained of the devasting shock of 1934 January 15 (Great North Bihar Earthquake), as both the machines were put out of action by the couplers getting dislodged after registering for about three minutes.

Kodaikanal Observatory
(*Director, T. Royds, D.Sc.*)

There has been a large percentage increase in all forms of solar activity when compared with the previous year.

Photoheliograms were obtained on 323 days, calcium flocculi plates on 316 days, calcium prominence plates on 301 days, and $H\alpha$ flocculi plates on 294 days. The taking of $H\alpha$ prominence spectroheliograms daily was discontinued as a routine measure from the beginning of the year, and these photographs are now confined to those days on which there are thick clouds when, mainly for instrumental reasons, the $H\alpha$ spectroheliograph will reveal prominences better than the K spectroheliograph. One calcium flocculus plate for each day was sent to the Solar Physics Observatory, Cambridge, as in former years.

Under the auspices of the International Astronomical Union, K prominence and $H\alpha$ disc spectroheliograms were collected from other observatories whenever complete observations were not possible at Kodaikanal. The statistical data regarding prominences seen at the limb and by absorption on the disc are published in half-yearly bulletins.

Daily character figures of solar activity according to $H\alpha$ bright flocculi and $H\alpha$ dark markings have been communicated to the Observatoire Fédéral, Zürich, for publication as in previous years. Daily character figures as derived from calcium flocculi from Kodaikanal photographs are furnished by the Solar Physics Observatory, Cambridge.

The Hale spectrohelioscope lent by the Mount Wilson Observatory was ready for regular use in April 1934. Owing to the feeble activity of the

Sun, few eruptions were observed with this instrument during the year, the most notable one being at latitude 25° N. and 47° E. of the central meridian on the 20th December.

The Director, the Assistant Director and Mr. C. P. S. Menon, Research Fellow of the Madras University, have been engaged throughout the year on the spectrophotometry of certain lines in the Sun's spectrum at different points between the centre of the Sun's disc and the limb. The lines studied were the H and K lines of ionised calcium and the Balmer series of hydrogen. Contours of these spectrum lines at different distances from the centre of the Sun's disc have been derived. Preliminary results are shown in the following tables :—

Central Intensities expressed as Percentages of Continuous Spectrum

Distance from Centre of Sun's Disc	0	0·44	0·65	0·77	0·86	0·95	0·98
H	14·8	14·9	16·1	16·9	17·1	21·4	22·8
K	14·3	15·6	16·5	16·8	18·7	19·8	21·2
Hβ	24·1	25·7	26·5	27·2	27·0	28·5	29·2
Hγ	27·5	27·5	27·8	27·9	29·0	32·3	34·0

Equivalent Widths in Angstroms

Distance from Centre of Sun's Disc	0	0·44	0·65	0·77	0·86	0·95	0·98
H	8·8	9·1	8·8	9·2	9·2	7·7	6·7
K	10·7	10·2	10·6	10·3	10·0	9·4	8·0
Hβ	3·3	3·1	2·9	2·8	2·5	1·8	1·6
Hγ	2·1	...	...	...	...	...	1·3

The longitude of Kodaikanal Observatory determined from the wireless time-signals transmitted for the International Determination of Longitudes, September to December 1933, is $5^h\ 9^m\ 52{\cdot}47^s$, east of Greenwich.

Union Observatory, Johannesburg
(*Union Astronomer, Mr. H. E. Wood, M.Sc.*)

26½-Inch Grubb Visual Refractor.—The number of visual micrometrical measures of double stars made during the year was 2959. With the eye-piece interferometer 207 measures of suitable double stars were obtained ; 22 photographic plates of double stars and star clusters were taken.

Franklin-Adams Star Camera.—During the year 1261 plates were

obtained with this instrument. The distribution of the plates was as follows :—

Minor planet regions and star maps	392 plates.
Variable star regions	833 ,,
Comet regions	36 ,,

A search was made for Comet Tuttle-Giacobini in January and February, but the comet was not found. Attempts were made to photograph Comet Encke between October 5 and November 4, but the comet was too badly placed for successful observation.

76 new minor planets were discovered during the year. On a plate taken on March 27 a nebulous trail was found which was thought to be the image of a comet. Later photographs gave sharp trails and a computation of the orbit showed that the object was a new minor planet (1934 FG).

Elliptic orbits for 12 new minor planets were computed during the year. 486 approximate positions and 105 accurately measured positions of minor planets were forwarded to the Astronomisches Rechen-Institut.

Occultations of Stars by the Moon.—The programme of the last few years has been maintained without alteration, and 143 occultations were observed during the year.

The results of the year's observations are as follows :—

		s	″
	1934·18	5·2	2·8
	·35	3·8	2·1
	·63	3·4	1·9
	·88	4·6	2·5
Mean for year	·59	3·9	2·1

These results are, as in former reports, from disappearances at the dark limb only. The second column indicates the time by which the Moon has arrived too early at any longitude, and the third column the amount by which the Moon is ahead of its tabular longitude.

A number of occultations observed by Messrs. G. E. Ensor and H. J. F. Burroughs, both of Pretoria, have been reduced and forwarded to Professor E. W. Brown.

Union Observatory Circulars.—Circulars Nos. 90, 91 and 92 were distributed during the year. Forty-five southern star maps were issued with these circulars.

The present state of the star map project is as follows :—

Maps already issued	507
Maps in hands of the Government printer	26
Maps still to be prepared	23
Total	556

Miscellaneous.—Dr. H. van Gent of the Leiden Observatory has continued his work on variable stars throughout the year. A new building to

house the twin 16-inch photographic refractor of the Leiden Observatory Foundation has been erected and is awaiting the telescope which is now undergoing final tests at Newcastle-on-Tyne.

The number of visitors to the observatory during the year was 1723.

Adelaide Observatory
(*Director, Mr. G. F. Dodwell, B.A., Government Astronomer*)

Latitude Variation.—Observations under the auspices of the International Latitude Commission have been continued, the observers being Messrs. A. L. Dawson, B.Sc., and A. E. Markey. 1320 pairs of latitude stars were observed on 126 nights, a considerable increase upon the number previously observed, partly owing to more favourable weather and partly owing to the stimulus of Dr. Kimura's recent visit to Adelaide. Observations of circumpolar stars and of stars in the Pleiades were made for determination of the value of one revolution of the micrometer screw, but owing to erroneous values of proper motion of several faint stars in the Pleiades, these stars could not be used for the determination. A re-survey of their positions is therefore to be desired.

The results of the latitude observations were sent to Dr. Kimura, President of the International Latitude Commission, at Mizusawa Observatory, Japan, for discussion, together with results from other international latitude stations. It is of interest to note that the range of movement at Adelaide, both of the latitude variation and of the "z" term, was smaller in 1933 than in the preceding year. The mean value of latitude of Adelaide in 1933 was $-34^\circ\ 55'\ 36''{\cdot}72$.

Time-Service and Longitude Work.—The time-service was continued as heretofore. A daily telegraphic comparison between the observatory Riefler Clock and the Shortt Free Pendulum Clock at the Adelaide University was of great advantage. By means of a weak bar magnet placed with its south pole 11 inches below the pendulum, Professor Kerr Grant has reduced the normal rate of the Shortt Clock closely to zero.

Bordeaux time-signals were received at 5.30 p.m. throughout the year, with a few gaps when atmospheric conditions were difficult. Following on the international longitude determinations in 1933 October–December a redetermination of the pivot errors of the transit-circle telescope was made. A discordance in the star observations during the longitude operations was traced to a fault in the determination of collimation error, similar to that which was experienced several years ago in the Indian Survey, and described by General J. T. Walker in his paper on "India's Contribution to Geodesy" (*Phil. Trans. Royal Society*, A, 1895, pt. ii, pp. 791–795).

Magnetic Survey.—During the year values of declination, inclination and horizontal intensity of terrestrial magnetism were obtained at 10 stations—Victor Harbour, Goolwa, Strathalbyn, Kuitpo, Nairne, Ceduna, Yalata, Flinders, Adelaide (West Park) and Belair. It has been found that the declinations at these stations, after being practically stationary for several years, commenced to increase their easterly value in 1923, and the values

are now nearly half a degree higher than in that year. Corresponding changes were found in the values of inclination and horizontal intensity.

Stellar Photography.—Photographs of various regions of the sky have been taken during the year in a search for comets, asteroids and objects of special interest. The desirability of better equipment for astronomical photography has been pointed out to the Observatory Committee, and it is hoped that this will be provided as soon as possible.

Seismology.—The Milne and Milne-Shaw Seismographs have been in continuous operation and results have been sent to the British Seismological Committee. Monthly Bulletins have also been sent to seismological observatories. During the year 152 earthquakes of moderate to great intensity were recorded, including 18 of destructive character, notably the great Indian earthquake of 1934 January 15. On April 26 seven large earthquakes were registered, a record for any one day since the seismographs were installed in 1909; most of these originated in the Pacific Ocean. A specially unstable period occurred between July 18 and 22, when 23 earthquakes were recorded, 6 of them giving large movements on the seismograms.

University Lectures and Educational Work.—The course of lectures on Astronomy for Surveyors, given to engineering students and others, was continued during the year.

The observatory was open for visiting purposes once a week, and more than 1000 visitors attended during the year, the visiting evenings being booked up for several months in advance.

Commonwealth Solar Observatory, Canberra, Australia
(*Officer-in-Charge, Mr. W. B. Rimmer*)

Sun Telescope.—The researches on the intensities and contours of Fraunhofer lines, indicated in last year's report, have been completed. About 100 additional line contours have been plotted, and all the available observational material has been used to study the following problems: (*a*) the relation between theory and observed equivalent breadths in 215 multiplets, (*b*) the relative sharpness of Fraunhofer lines and its relation to excitation potential, (*c*) the relation between the theoretical and observed line structure, (*d*) the relation between the coefficient of line absorption in the Sun and intensity of light in the Sun's spectrum, (*e*) the intensities of lines in related multiplets, and the effect of wave-length, (*f*) the astrophysical observation of oscillator strengths, and (*g*) the relative abundance of elements in the Sun.

Papers describing the results and tabulating the observational data are in process of publication.

The Hale Spectrohelioscope.—A special building for this instrument has been completed. A suitable grating is being obtained to complete the installation.

Atmospheric Electricity.—Atmospheric electric observations have included the continuous recording of the potential gradient as well as measurements of the conductivity, number and mobility of the small ions by more refined methods than had been previously employed.

Modifications have been effected to the apparatus for continuously and automatically recording the mean life, and the rate of production and concentration of the small ions. Daily records have been obtained since 1934 June 1, and these await reduction. A description of the apparatus and method is in course of publication.

Cosmic Radiation.—For the measurement of cosmic radiation a high-pressure ionisation vessel has been constructed and installed in a specially erected laboratory provided with thermostatic control. The measurements are made by an automatic compensation method, and are capable of detecting variations of the order of 0·1 per cent. in the relative intensity of the radiation.

Measurements of the absolute intensity of the radiation have been made to a rather less degree of accuracy, using a portable apparatus the residual radiation of which was determined by observations in a tunnel.

Radio Research.—Observations of the direction, intensity and duration of sources of "atmospherics" have been continued with the Continuous Recorder.

At the beginning of the year the cathode-ray direction finder at Melbourne was moved to Toowoomba, Queensland, and simultaneous observations were made regularly throughout the summer months. This has enabled the main "atmospherics" centre for Eastern Australia to be examined in more detail.

Publications.—Publications during the year included two papers, "Atmospheric Electric Observations," and "Some Observations of the Average Life of Small Ions and Atmospheric Ionisation Equilibria," which appeared in *Gerlands Beitrage zur Geophysik* (vol. 41, pt. 1, pp. 1–57, 1934). Memoir No. 3 of the Commonwealth Solar Observatory, "Measurements of Atmospheric Ozone," and Memoir No. 4, "Atmospheric Potential Gradient Observations," have been printed and distributed. Two other papers are in process of publication.

General.—The programme of work, as outlined in the reports of previous years, has been continued.

Melbourne Observatory

(*J. M. Baldwin, M.A., D.Sc., F.Inst.P., Government Astronomer*)

The observation of the list of Fundamental Stars with the 8-inch transit-circle has been continued. During the year several nights were devoted to the determination of the personal equation of the transit-circle observers. Observations of southern long-period variable stars with the 8-inch equatorial have also been made throughout the year, and the results have been published regularly in *Popular Astronomy* with those of other members of the American A.V.S.O.

Owing to lack of funds and depleted staff, no progress has been made in printing the fourth and fifth *Melbourne General Catalogues*, or vols. iv and v of the *Astrographic Catalogue*. The only progress that has been possible in the astrographic work has been in the revision of the positions of reference stars and in the computation of definitive plate constants.

Seismological and magnetic work has been carried on, and seismological bulletins have been issued quarterly. The sheets containing the hourly values of the magnetic elements for the years 1928 to 1931 have been typed ready for reproduction, but up to the present no funds have been available for the publication of these records.

Riverview College Observatory, Sydney, N.S.W.
(Director, Rev. W. O'Leary, S.J.)

The Riverview seismological station was founded in 1908 by the Rev. E. F. Pigot, S.J., and bulletins have been issued regularly since 1909. Father Pigot hoped to organise regular astronomical work, but he died in 1929 before his plans were completed. The present Director arranged with Dr. J. Voûte, Director of the Lembang Observatory, Java, that the two observatories should collaborate in photographic work on southern variables (cf. *Lembang Annals*, 2, D 3). Dr. Voûte very generously presented to Riverview an English equatorial mounting, designed by himself and constructed at Lembang by A. J. Witlox, together with a 4-inch guiding telescope, a 60 mm. Zeiss Astrotriplet lens (f.l. 270 mm.), a 43 mm. Zeiss Triotar lens (f.l. 150 mm.) and a 70 mm. Schneider Xenar lens (f.l. 240 mm.). The Zeiss driving clock for this instrument was purchased for the observatory by the Council for Scientific and Industrial Research. A Watson 4-inch lens and a Ross 6¼-inch lens, mounted on a 7-inch Cooke equatorial refractor, complete the photographic equipment.

Certain selected areas are photographed every clear night at Lembang and at Riverview with similar instruments, the plates, exposure time for each region, and developer being the same at both observatories. Nearly 4000 plates have been taken at Riverview since August 1931. At present attention is being directed mainly to Cepheid variables. Results will be published partly in the *Lembang Annals* and partly in *Riverview Publications*, the first of which, it is hoped, will be issued shortly. The staff consists of the Rev. W. O'Leary, S.J., Director, the Rev. D. O'Connel, S.J., and P. F. Rheinberger, Assistant.

Sydney Observatory
(Director, Mr. James Nangle, Government Astronomer)

Work on the Astrographic Catalogue has been continued throughout the year. Observations of 340 plate stars have been made and reduced. This is much less than usual, owing to adverse weather and illness of the Transit Observer. The measurement of plates for vols. xiii, xv, and xvi has been completed, and measurements of plates for vol. xiv are nearly completed.

One hundred and thirty-six tremors have been recorded on the Milne Seismograph. Monthly bulletins have been forwarded to the principal Seismological Observatories.

The time-service has been conducted with regularity through the year, and the usual routine work necessary for civil purposes has also been carried out.

A total of 1173 visitors during the year have been conducted over the observatory, and lectures on astronomy have been given to university and other students. The buildings and equipment of the observatory have been maintained in good order.

The staff remains the same as last year.

The Dominion Observatory, Wellington, New Zealand
(*For the Year* 1933)

(*Director, Dr. C. E. Adams, Dominion Astronomer and Seismologist*)

The time-service has been maintained and the regular daily signals transmitted. The total number of signals sent by the observatory was 2450. The signals are transmitted through the Government station ZLW and through the broadcasting station 2YA at Wellington. The broadcasting station at Christchurch, 3YA, rebroadcasts the signals from 2YA. The usual method of recording radio time-signals by using a chronograph with hand key has now been supplemented by the installation of a Marconi Magnetic Drum Recorder. The first signal automatically recorded was Honolulu, NPM, on November 17^{d} 3^{h} G.C.T. Only short-wave signals have so far been recorded automatically. 920 signals on 9 call-signs were received, including both mean time and rhythmic signals.

Observations of star transits and rhythmic time-signals were made during October and November 1933 by Messrs. R. C. Hayes and I. L. Thomsen in accordance with the International Longitude Programme. The observations include 365 star transits and 63 wireless time-signals. Owing to the smallness of the observatory staff little progress has been made in the reduction of these observations, and the work is far in arrears.

The period of Summer Time is now defined by the Summer Time Amendment Act, 1933, as commencing on the last Sunday in September and ending on the last Sunday in April.

Commencing in April 1933, the daily observation of the Sun's disc by the projection method, with the 5-inch Grubb refractor belonging to the Wellington Philosophical Society, was made a routine duty of the observatory. Mr. I. L. Thomsen is the observer, and the results are sent regularly to Professor W. Brunner at Zürich, under the auspices of the International Astronomical Union. From April to December observations were made on 99 days, and 80 per cent. of these showed no evidence of sunspots.

By co-operation with the New Plymouth Astronomical Society, a total of 18 observations of occultations were secured, and the results have been forwarded to Dr. L. J. Comrie.

While passing through Wellington, members of the scientific staff of the Byrd Antarctic Expedition visited the observatory, and Dr. Poulter, leader of the scientific section, left a number of meteor reticles to be used in New Zealand in conjunction with the Antarctic observation of meteors.

On August 7 an independent discovery of the white spot on Saturn was made by Mr. I. L. Thomsen.

During the year 917 earthquakes were recorded on the seismographs at the observatory and subsidiary stations. The total number of earthquakes felt in New Zealand was 108,—71 of these being felt in the North Island and 45 in the South Island. No earthquakes above 7 on the Rossi-Forel scale were recorded. Epicentres of 9 earthquakes, which were of high intensity, were determined. There are thirteen subsidiary stations with various instruments for recording earthquakes. They are as follows: Suva, Arapuni, Tuai, New Plymouth, Hastings, Dannevirke, Bunnythorpe, Takaka, Wellington, Greymouth, Glenmuick, Christchurch, Chatham Islands. Reports are also received from Apia. Seismograph records of the Buller earthquake, 1929 June 16–17, were obtained from observatories all over the world, and Mr. L. Bastings, M.Sc., F.Inst.P., has been making an intensive study of them. He has already published a discussion (*New Zealand Journal of Science and Technology*, **15**, 128–142, *Dominion Observatory Bulletin* No. 86) of the material from the nearer hemisphere, dealing with the magnitude, focal depth, and nature of the original disturbance, together with the travel times and velocities of the preliminary movements in this hemisphere. He has also made considerable progress in reading and interpreting the wealth of material from the antipodes, and it is hoped to publish shortly some far-reaching conclusions derived from the analysis of these data.

The Wellington City Council has kindly given permission for the observatory staff to use the 9-inch Cooke photo-visual refractor. This is very welcome, since, apart from the transit instruments, the observatory has no astronomical equipment suitable for the usual observations.

Considerable help has also been given by the New Zealand Astronomical Society in the form of observations by reliable amateurs.

Preliminary earthquake reports and corrections to wireless time-signals transmitted from the observatory through station ZLW are forwarded to institutions which require them every month. Bulletins 85 to 91 and Seismological Reports E31–33 have been printed and distributed.

Mr. Robert Barker's Observatory, Cheshunt, Herts

In 42 observations of Saturn and satellites the position angles and light fluctuations of Rhea, Dione and Tethys were obtained and further details gained of the variability of Iapetus. 142 observations of the Moon were made and many hitherto unrecorded features (chiefly clefts) were noted.

Telescope.—12·6-inch clock-driven Calver equatorial.

Mr. A. F. Bennett's Observatory, Leiston, Suffolk

Observations have been made when practicable on the disc and limb of the Sun. The Cooke refractor has also been used for the observation of the planets and some variable stars.

Eleven occultations of stars by the Moon were observed and the results have been sent to the computing section of the B.A.A. The altitude of the observatory has been verified by a series of theodolite observations referring it to the nearest ordnance bench mark.

Wolsingham Observatory (Rev. T. E. Espin), Tow Law, Co. Durham

We regret to announce the death on 1934 December 2 of the Rev. T. H. E. C. Espin, founder and director of this observatory. Failing health prevented him making any observations during the year.

The survey for new double stars in the zones $+35°$ to $+40°$ and the programme of remeasurement of certain known pairs have been continued by his assistant, W. Milburn, and the results communicated to the Society.

Mr. J. Evershed's Observatory, Ewhurst, near Guildford

The past year has been favourable for solar work, and spectroheliograms in $H\alpha$ light for the estimation of character figures were obtained on 110 days. The results have been sent to Dr. Brunner. Prominence plates were taken on 74 days. Both the disc and limb photographs give evidence of slowly increasing prominence activity.

Fifty prominence spectra have been photographed and measured for rotation speed and shift of the H and K lines towards red. An analysis of the results for the six years 1929–34 has been completed, and shows that the high angular speed of rotation previously recorded has been maintained during this period of low solar activity. 401 spectra have been measured in this period, giving the angular speed $\xi = 16°$ approximately, nearly constant in latitude except for a lower value between lat. $\pm 15°$–$20°$, which was also a region of low activity.

The mean shift to red for H and K in these spectra corrected for one atmosphere is $+0{\cdot}0122$ A., which is $1{\cdot}5$ times the Einstein effect. It is perhaps of significance that the high latitude prominences, those outside the range of sunspot disturbance give a lower mean shift, approximately equal to the relativity shift.

The solar rotation given by lines in the reversing layer has also been studied, and 28 east and west spectra in the yellow and 90 in the green region have been photographed and measured. The D1 line of sodium and the b_1 and b_2 lines of magnesium yield rotation values from 1 to $2\frac{1}{2}$ per cent. greater than the values from neighbouring lines representing lower levels. The method of obtaining these spectra and measuring them, described in *M.N.*, **93**, 165, has yielded far more reliable results than have been obtained previously by methods in common use.

Measures of some of the stronger iron lines in arc and Sun made during the year give variable values of the shift towards the red in the Sun. The mean values both at the centre and limb agree rather closely with the relativity shift.

Other work undertaken during the year includes high-dispersion photographs of sections of the Sun's disc for the study of small Doppler shifts, and limb and centre spectra in the red for estimating the limb shift of certain iron lines.

Mr. F. J. Hargreaves's Observatory, Kingswood, Surrey

A few further measurements of double stars have been made with the comparison-image micrometer and recorded in the *Handbook of the B.A.A.* The instrument has now been dismantled in view of the impending addition of a similar instrument to a large refractor elsewhere.

During the period 1933 December 5 to 1934 June 22, 612 central-meridian transits of markings on Jupiter were obtained.

The figuring of the 14½-inch Pyrex mirror referred to in the last report was completed in January 1935. The performance is satisfactory and the mirror is remarkably little subject to disturbance of figure or focus by temperature changes.

Mr. Newbegin's Observatory, Worthing, Sussex

The usual routine work has been discontinued this year and the 6¼-inch refractor was only used for solar work occasionally. Advantage was taken of the minimum period of solar activity to complete the construction of the spectrohelioscope and the instrument was erected on March 22. Considerable delay in bringing the instrument into use occurred, as it was found on testing the concave mirrors that they did not conform to the specifications; they were sent back to the makers for correction. They were returned on September 1 and proved satisfactory. The adjustments were proceeded with as adverse weather conditions permitted during the remainder of the year, and systematic observations will be commenced in 1935.

A description of the spectrohelioscope will be found in *M.N.*, 95, 179.

Mr. B. M. Peek's Observatory, Solihull, Birmingham

Physical observations of the planet Jupiter have constituted the bulk of the work of the observatory. During the 1933–34 apparition 1012 determinations of longitude were made from transits of spots and other physical features across the planet's central meridian.

Photometric observations of Nova Persei 1901 have been continued.

During 1934 ten occultations of stars by the Moon were observed; the records have been forwarded to Dr. L. J. Comrie.

A detailed study was undertaken during the early part of the year of a large number of observations of the outburst of activity which occurred in Saturn's equatorial regions in 1933 August to September; as a result a full discussion of the phenomena was published in *B.A.A.J.*, vol. xliv, No. 6, as an Interim Report of the Saturn Section.

Rev. T. E. R. Phillips's Observatory, Headley, near Epsom.

The usual programme has been continued.

During the first half of the year special attention was given to Jupiter, and over 1500 central meridian transits of spots and other markings were recorded. The circulating drift of objects in the S. Tropical region of the surface was still in evidence at the close of the planet's apparition.

The preparation of the 1928–29 Memoir of the Jupiter Section of the B.A.A. has been completed, and the Memoir (27th Report of the Section) presented to the Association.

A paper containing the results of double star measurements with the 8-inch refractor made since the beginning of 1931 has been communicated to the Society.

Dr. R. L. Waterfield has continued his photographs of galactic star clouds and diffuse nebulæ.

As far as the weather has permitted systematic observations of Nova Herculis have been made by both observers.

Mr. F. J. Sellers's Observatory, Muswell Hill, London

The 5-inch equatorial refractor has been used on 214 days during the year for solar observation, sunspots, prominences and faculæ being recorded and measured. The more interesting results have been communicated to the British Astronomical Association in the quarterly Solar Activity Reports.

Drawings have been made of all spots and prominences observed and the latter have been charted, one chart for each solar rotation.

Since the sidereal clock was installed at the beginning of the year, eight Lunar occultations have been observed and reduced ; the results are being communicated to the B.A.A. Computing Section.

The $8\frac{1}{2}$-inch reflector, recently re-silvered, has been employed in planetary observation and for occultations ; also several daylight observations of Nova Herculis (1934) were made.

This being the first report from this observatory, the position and co-ordinates are given below.

Long. $+0^h\ 0^m\ 34^s{\cdot}31$; Lat. $+51^\circ\ 35'\ 13''{\cdot}4$.
$\log \rho \sin \phi'$ 9·89204 ; $\log \rho \cos \phi'$ 9·79422.
Altitude 111 metres.

Dr. W. H. Steavenson's Observatory, West Norwood

Observations were made on 211 nights during the year. Of this total, unusually large for the London area, the first ten months accounted for 191 nights.

The $20\frac{1}{2}$-inch Hindle reflector was, as usual, chiefly employed in the observation of variable stars and novæ in their fainter stages.

626 observations of 24 long-period and irregular variables were made, and these have been communicated to the Variable Star Section of the British Astronomical Association. 281 observations of 12 novæ were also made during the year, and some of these have already been communicated to the Society. A faint star, suspected to be identical with Nova Vulpeculæ (1670), was detected in July, and formed the subject of a special paper communicated in December.

The mirrors of the reflector were re-silvered in April and October.

NOTES ON SOME POINTS CONNECTED WITH THE RECENT PROGRESS OF ASTRONOMY

Minor Planets

The lettering gives approximately the date of discovery; in the first half of January the first letter is A, in the second half B, the first letter changing every half-month, I, J being treated as a single letter; December discoveries begin with X or Y.

Two hundred and fifty-two planets were discovered, or first announced, in 1934, as follows :—

S. Arend (Uccle) CF, CG, CH, CJ, CK, CM, CK_1, FA, FB, FC, KA, XD; Mdlle. O. Bancilhon (Algiers) DA; W. R. Boyd (Harvard) object detected in search for Hidalgo (Harvard Card 309); L. Boyer (Algiers) EA, XA, XB, YA; J. Comas Sola (Barcelona) WA; E. Delporte (Uccle) AH, CN, CO, CP, CQ, CR, CS, CT, CK_1, EB, EC, GA, GB, HA, QA, RA, RB, RC, RD, RE, RF, RO, TA, UA, UB, VB, XC, XE, XF; C. Jackson (Johannesburg) DB, EC, EG, FD, FG, FK, FL, FM, FN, FO, FP, FQ, FR, GT, GU, GV, HC, HD, HE, HF, HG, HH, JD, JE, JF, JG, JH, JJ, KB, LD, LE, LF, LG, LH, LJ, LK, LL, LM, LN, LO, LP, ND, NE, NF, NG, NH, NJ, NK, NL, NM, NN, NO, NP, NQ, NR, NS, NT, NU, PG, PH, PJ, PK, PL, PM, PN, PO, PP, PQ, PR, PS, PT, PU, PV, PW, PX, PY, PZ, PA_1, QB, QC, RG, RH, RJ, RK, RL, RT, RU; H. M. Jeffers (Lick) object near Jupiter May 9, planet not satellite (B.Z. 17) (H.C. 303); M. Mündler (Heidelberg) CA, CA_1, FE, also 1932 PF (found on old plates); G. Neujmin (Simeis) ED, EE, GR, JA, JB, PE, PF, RG, RM, RN, SA, TD, TE, TF, TG, TH, TJ, TK, TL, VC, VD, VE, VF, VG, VH, VJ, VK, VL, VM, VN, VO, VP, VQ, XG, also 1925 VH (found on old plates); G. Pels (Leiden) 1929 SH (found on old plates); K. Reinmuth (Heidelberg) in 1933, not previously announced, XA, XB, XC, XD, XE, XF, XG, XH, in 1934 AB, AC, AD, AE, AF, AG, CB, CC, CD, CE, CU, CV, CW, CX, CY, CZ, CB_1, CC_1, CD_1, CE_1, CF_1, CG_1, CH_1, CJ_1, EF, FF, GC, GD, GE, GF, GG, GH, GJ, GK, GL, GM, GN, GO, GP, GQ, LA, LB, LC, NA, NB, NC, OA, OB, PA, PB, PC, PD, RE, RO, RP, RQ, RR, RS, TB, TC; G. Reiss (Algiers) BA, CL; J. Renaux (Algiers) GS; L. Terkan (Budapest) BB; G. van Biesbroeck (Yerkes) CL_1, FH, FJ; H. van Gent (Johannesburg) 1933 UW_1.

The following identities are announced and numbers assigned :—

311 = 1934 AA; 323 = 1934 JC; 392 = 1933 SW = 1933 UZ; 485 = 1933 FZ_1; 779 = 1908 FA; 848 = 1934 CV; 872 = 1900 FL; 918 = 1907 YA = 1907 YF; 972 = 1906 SM; 975 = 1912 OE; 1007 = 1934 FE; 1014 = 1932 WH; 1022 = 1910 KO; 1032 = 1917 BL; 1050 = 1908 EC; 1063 = 1923 NF; 1083 = 1910 JH; 1089 = 1919 FG = 1927 WB; 1113 =

1909 GL ; 1244 = 1921 JS ; 1245 = 1906 TR = 1914 VV ; 1248 = 1901 HH = 1930 DU ; 1255 = 1905 RL ; 1265 = 1910 KP = 1911 MV = 1929 CS = 1934 CD_1 ; 1266 = 1927 BD = 1933 BM = 1934 EC ; 1267 = 1926 GV = 1927 SH = 1930 HD ; 1268 = 1930 HJ ; 1269 = 1930 SH = 1931 VY ; 1270 = 1930 YE ; 1271 = 1931 TN ; 1272 = 1917 CW = 1931 TZ ; 1273 = 1932 PF ; 1274 = 1918 EF = 1926 AA = 1928 RX = 1932 WC ; 1275 = 1932 WG ; 1276 = 1933 BA ; 1277 = 1933 HA ; 1278 = 1933 LA ; 1279 = 1933 LB ; 1280 = 1933 QB ; 1281 = 1933 QJ ; 1282 = 1933 QM_1 ; 1283 = 1925 SC = 1931 VE_1 ; 1284 = 1933 OP = 1933 QP ; 1285 = 1933 QF = 1933 RB ; 1286 = 1928 SE = 1933 QH ; 1287 = 1933 QL ; 1288 = 1933 QM ; 1289 = 1928 QD = 1933 QR ; 1290 = 1933 QL_1 ; 1291 = 1907 AJ = 1933 RA ; 1292 = 1905 RX = 1907 YH = 1933 SH ; 1293 = 1933 SO ; 1294 = 1917 BR = 1933 UB_1 ; 1295 = 1933 WD ; 1296 = 1933 WE ; 1297 = 1927 VB = 1934 AD ; 1298 = 1904 OR = 1934 AE ; 1299 = 1934 BA ; 1300 = 1934 CL ; 1301 = 1934 EA.

The numbers from 1265 to 1301 are new.

Among the unnumbered planets :—

1898 DW = 1931 VW ; 1911 LU = 1934 LD ; 1916 *o* = 1928 SF ; 1916 AU = 1929 CG_1 = 1933 FF_1 ; 1924 SV = 1930 WD ; 1925 DB = 1933 QK_1 ; 1925 VF = 1933 UT ; 1926 XD = 1928 HH ; 1928 KC = 1934 LE ; 1930 UF = 1933 QF_1 ; 1931 EB = 1933 SP ; 1931 TO = 1934 GT.

The following planets have been named :—

746 Marlu ; 759 Vinifera ; 764 Gedania ; 765 Mattiaca ; 766 Moguntia ; 773 Irmintraud ; 777 Gutemberga ; 778 Theobalda ; 786 Bredichina ; 788 Hohensteina ; 912 Maritima ; 947 Monterosa ; 949 Hel ; 989 Schwassmannia ; 990 Yerkes ; 991 Donalda ; 992 Swasey ; 993 Moultona ; 1004 Belopolskya ; 1116 Catriona ; 1118 Hanskya ; 1166 Sakuntala ; 1170 Siva ; 1190 Pelagia ; 1202 Marina ; 1204 Renzia ; 1235 Schorria ; 1239 Queteleta ; 1240 Centenaria ; 1242 Zambesia ; 1243 Pamela ; 1244 Deira ; 1245 Calvinia ; 1261 Legia ; 1265 Schweikarda ; 1267 Geertruida ; 1274 Delportia ; 1276 Ucclia ; 1280 Baillauda ; 1281 Jeanne ; 1284 Latvia ; 1285 Julietta ; 1286 Banachiewicza ; 1288 Santa ; 1290 Albertine ; 1291 Phryne ; 1292 Luce ; 1293 Sonja ; 1294 Antwerpia ; 1299 Mertona ; 1300 Marcelle.

Planet 1301 has the high inclination 33°·923, which is exceeded only by Hidalgo, Pallas, Zerlina and Celestia ; Troilus and Mireille come next.

As the last report anticipated, the interesting planet 944 Hidalgo has returned to visibility, after being out of sight for twelve years, during which it travelled out to the orbit of Saturn ; it passed within less than a unit of Jupiter at the end of 1922, and suffered perturbations which lengthened the period by four months ; these were investigated by C. Vick in *R.I. Circ.* 1015 ; he gave the following predicted elements : T 1935 March 12, ω 57° 38′ 1″, Ω 21° 15′ 4″, *i* 42° 32′ 32″, ϕ 40° 59′ 35″, *n* 253″·60, equinox 1935·0. The observed value of T is a week earlier, which increases the

value of n to 254″. An ephemeris based on the predicted elements is given in the *B.A.A. Handbook* for 1935; corrections to reduce to the observed value of T are given in *B.A.A. Journal*, 45, No. 1; the distance from the Earth is large in 1935, but the high north declination (54° in June) will facilitate observation. The perihelion distance is just two units. The recovery of the planet was made by Prof. G. Neujmin at Simeis on October 3; magnitude 13.

Dr. Stracke has published a pamphlet giving an estimate of the number of planets that are within reach of present instruments; it is about 44,000; but he points out that observers should concentrate more especially on keeping interesting planets under observation, and preserving new discoveries from subsequent loss.

The following is a summary of theoretical work: *J.O.*, **17**, No. 1, E. de la Ville Marque studies the motion of planets of the Flora type; No. 2, L. Boyer gives a revised orbit of 173 Ino; No. 7, A. Razdolsky studies the motion of the Trojan 659 Nestor. *A.S.P.*, 46, 301, S. H. Levy determines general perturbations of planets of the Hecuba type, especially 121 Hermione.

A.N. 6049 contains osculating elements of the Trojan 588 Achilles from 1905 to 1929 by N. Komendantow; 6062 has a note on the remarkable light-changes of 323 Brucia; 6040 contains a note by H. Krumpholz on a close approach of 21 Lutetia to 275 Sapientia. They were only 0″·8 apart on 1934 March 23^{d} 0^{h} 23^{m} G.C.T. A. C. D. C.

Comets

For the first time since 1876 a year has passed during which no unexpected comets were discovered; two objects that were announced as comets proved to be minor planets. However, the year has seen much useful cometary work. Seven comets, of which six were short-period ones, the seventh hyperbolic, were under observation; and Dr. Jeffers accomplished a photographic triumph in obtaining images of comet Wolf (1) in September, when its photographic magnitude, compared with the polar sequence, was 19·1.

Comets Geddes and Whipple were observed for several months; Geddes till May, and Whipple till November, when its magnitude was 18 (again by Dr. Jeffers). Comet 1925 II (Schwassmann-Wachmann 1) was observed for the eighth consecutive year; it is likely to be under observation every year for a very long period, which will make its orbit as accurately known as those of the major planets; doubtless tables of its motion will be constructed, the eccentricity being considerably less than that of Mercury. It underwent another of its frequent outbursts of light, the magnitude changing from 18 to 13 between March 10 and 14 (van Biesbroeck); in mid-April van Biesbroeck noted the magnitude as 15, the diameter of coma 30″. Encke's comet was detected by Dr. Jeffers at Lick Observatory on July 10; Professor van Biesbroeck then found an image on a plate exposed on July 8; the magnitude was then $15\frac{1}{2}$; it was well observed in America and Europe till the end of August,

when it had risen to magnitude 6 or 7 ; it was then lost in the Sun's rays. Later observations may have been made in the southern hemisphere, but they have not come to hand. Very accurate predictions were made by Drs. Matkiewicz and Idelson ; they were both within an hour of the observed time of perihelion. Two other periodic comets, which do not pass perihelion till 1935, were detected before the end of 1934. Dr Jeffers detected Reinmuth's comet (magnitude 16) on November 5 ; the indicated time of perihelion is 0·4 day later than that predicted in the *B.A.A. Handbook*.

Ref. No.	Year and Number of Comet	Name		*T*	ω	Ω	*i*
					° ′ ″	° ′ ″	° ′ ″
598	1931 V	Carrasco		Nov. 30·6743	110 18 49	18 5 8	58 4 58
601	1932 III	Kopff		Aug. 21·1495	19 41 46	263 55 55	8 42 33
612	1933 IV	Whipple		July 31·5519	190 15 27	188 34 9	10 12 58
612	1933 IV	Whipple		July 30·7810	189 59 11	188 35 1	10 13 9
613	1934 I	Wolf (1)		Feb. 27·7718	160 48 55	204 11 7	27 15 49
614	1934 II	Encke	P.	Sept. 15·2002	184 56 37	334 39 20	12 33 32
614	1934 II	Encke	P.	Sept. 15·2254	184 56 57	334 39 11	12 33 35
			Obs.	Sept. 15·26			
...	1935	Reinmuth	P.	May 1·42	8 50 9	124 57 57	8 4 2
			Obs.	May 1·8			
...	1935	Schwassmann-Wachmann (2)	P.	Aug. 31·39	357 59 31	126 5 24	3 43 52
			P.	Aug. 24·1	357 54 22	126 6 49	3 43 46
			Obs.	Aug. 28·8			

There was an erroneous announcement of the detection of comet 1929 I (Schwassmann-Wachmann 2) on August 15 ; Mr. L. E. Cunningham showed that the object observed was planet 44 Nysa. The comet was detected on December 11 by Professor G. van Biesbroeck at Yerkes, the magnitude being 16. The indicated date of perihelion is about 1935 August 28·8, which is intermediate between the two predicted values given in the Orbit Table. The early detection of this comet is fortunate, as it will be nearly behind the Sun at the time of perihelion passage. Mr. H. Q. Rasmusen gives in *A.N.* 6042 a computation of the motion of comet 1929 III, Neujmin, from 1929 to 1940 ; he finds for the date of the next perihelion 1940 May 8·26.

With regard to the hyperbolic orbit of 1931 V, Mr. Herget has carried back the perturbations to the beginning of 1929, finding that the excess of *e* over unity was only half as great as at perihelion ; still smaller values were indicated before that, so that the excess over unity may be ascribed to planetary action.

A.J. 1002 and 1003 contain a study by E. Cherrington, jun., on the repulsive force indicated by the outward motion of the tail matter of Morehouse's comet 1908 III. Fourteen condensations were studied ; they gave

values of the repulsive force varying from 1367 to 60 times gravity, the mean being 391 times. Values of the same order had been found by A. Kopff and S. Orlow. The ejection velocities from the head varied from 67 to 4 km./sec.

P.A. for April contained an article by Mr. Wen Shion Tsu on ancient cometary observations in China. In particular he records a comet, not previously mentioned in European works, which was seen in China in the south-west in the evening in the first month of B.C. 163. This was pos-

Ref. No.	log q	Period in Years or Eccentricity e in Hyperbolic Orbits	Equinox	Computer	Reference
598	0·367511	(e = 1·002637)	1950·0	P. Herget	*A.J.*, **43**, 121.
601	0·227576	6·59591	1932·0	F. E. Seagrave	*A.J.*, **44**, 7.
612	0·396956	7·50301	1933·0	A. D. Maxwell	*Pubs. Michigan Obs.*, **5**, 15.
612	0·396567	7·51023	1933·0	M. Davidson	*Obs.*, **57**, 202.
613	0·389206	8·32896	1934·0	M. Kamienski	*Warsaw Circ.*, 12.
614	9·520896	3·28388	1934·0	L. Matkiewicz	*Pulkovo Obs. Circ. No.* 10.
614	9·520919	3·28400	1934·0	N. Idelson	
...	0·272146	7·32060	1935·0	J. T. Foxell, A. E. Levin	*B.A.A. Handbook*, 1935.
...	0·321135	6·43541	1934·0	H. Q. Rasmusen	*A.N.*, 6069.
...	0·321037	6·4119	1935·0	P. J. Harris, J. D. McNeile	*B.A.A. Handbook*, 1935.

sibly Halley's comet; no observation at that return had been previously known.

The orbit of Kopff's comet by Mr. F. E. Seagrave was published just before his death. It was derived from the observations of 1932 only, and the period appears to be too long by 0^{y}·04. A. C. D. C.

Solar Activity

Sunspots.—It now appears certain that the minimum of the eleven-year solar cycle occurred in the latter half of 1933 and that the new cycle is being established, though in a somewhat sporadic manner. The mean area of sunspots, corrected for foreshortening, is approximately 110 millionths of the Sun's hemisphere for 1934, as compared with 88 millionths for the previous year. From February to August there were several significant groups; then a less active period intervened and continued, with occasional minor outbreaks of spots, until the end of the year.

The largest group crossed the disc from April 15 to 28 (central meridian passage—April 21·9) in latitude 29° S.; its maximum area, chiefly concentrated in the leader spot, was about 1000 millionths of the Sun's

hemisphere. Spots in this region, renewed by a fresh outbreak before the group returned to the central meridian on May 19·7, continued until their fifth transit of the disc from August 6 to 18.

The following groups of spots, designated by their respective times of central meridian passage and their latitudes, were observed spectroscopically to be more than usually active :—

(1) Feb.	3·3	+28°	
(2) Feb.	15·4	+ 7°	
(3) [Mar.	12·8]	−28°	
(4) Apr.	21·9	−29°	
(5) May	19·7	−31°	
(6) July	12·9	+25°	
(7) Aug.	12·5	−29°	
(8) Aug.	14·7	+ 4°	
(9) [Sept.	11·1]	+ 7°	
(10) Nov.	7·0	+23°	

A square bracket denotes that the group was not visible at the time of its central meridian passage.

Spots nos. 1, 3, 4, 5, 8 and 10 were associated with bright eruptions of minor extent observed in *Hα*, five eruptions being observed in the case of no. 4. Radial velocities of the order of 50–75 km./sec. pertaining to dark flocculi were observed near spots nos. 2, 4, 5, 6 and 9. Notes on these active groups are given in the current numbers of *The Observatory*.

The first high latitude groups of the new cycle for which magnetic polarities could be determined at Mount Wilson appeared in 1933 October. Since then sufficient data have been obtained to show clearly the anticipated reversal in sign at solar minimum of magnetic polarities, observed now for the third successive epoch.

1934 was a year of fewer terrestrial magnetic disturbances than 1933, and of the six minor storms recorded at Greenwich (Abinger) only one was associated with the transit of a sunspot across the central region of the disc.

H. W. N.

Prominences, 1934.—There has been a large percentage increase in prominence activity over that of 1933. The mean daily areas and numbers of calcium prominences as derived from Kodaikanal spectroheliograms are as follows :—

Areas

	North	South	Total
1934 January to June ...	... 1·80	1·75	3·55 sq. mins.
July to December ...	... 1·99	2·05	4·04 ,,

Numbers

	North	South	Total
1934 January to June ...	... 6·38	6·55	12·93
July to December ...	... 6·86	6·78	13·64

Compared with the previous year, calcium areas show an increase of 65 per cent. and numbers of 44 per cent. The activity is almost equally divided between the northern and southern hemispheres. The distribution

in latitude shows a maximum activity near 45°, which is about 5° nearer the poles than the maximum in 1933.

Eight metallic prominences were observed during 1934, as against 3 in the previous year. Of these, 2 were observed in the northern hemisphere and 6 in the southern hemisphere, their mean latitude being 26° from the equator. Displacements of the hydrogen line in the chromosphere and prominences observed during the year numbered 137, while those observed during the previous year were 86. Of the displacements, 66 were towards the red, 68 to the violet and 3 both ways simultaneously.

There has been an increase in the case of bright reversals and displacements of the *Hα* line observed on the disc in the neighbourhood of spots. Bright reversals numbered 118 as against 78 in the previous year. As against 3 displacements of the *Hα* line observed during 1933, those observed in 1934 numbered 14; of these 7 were towards the red, 4 towards the violet and 3 both ways simultaneously. D3 was observed as a dark line on 106 occasions as against 68 in the previous year.

The mean daily areas of prominences projected on the disc as hydrogen absorption markings amounted to 1990 millionths of the Sun's visible hemisphere, as against 1104 * during the previous year, representing an increase of 80 per cent. Their distribution in latitude is similar to that of calcium prominences. T. R.

Solar Research

Corona.—Goudsmit and Ta-You Wu (*Ap. J.*, **80**, 154) suggest that the great width of the coronal line λ 5303, reported by Lyot and others, is a natural width, and therefore evidence of an excessively short life in the excited state of the atom concerned. Such short life-times are frequently associated with states produced by two excited electrons having a total energy greater than the ionization energy. A detailed but necessarily approximate calculation indicates that a neutral helium atom with two excited electrons should give a number of lines in the visible spectrum, and the authors suggest that a laboratory search should be made for such lines. This suggestion, originally made in a less satisfactory form by Rosenthal in 1930, is discussed by Beutler (*Z. f. Ap.*, **9**, 387) with special reference to the absence of ordinary helium lines from the coronal spectrum. In this connection it is interesting to note that H. D. and H. W. Babcock (*Pub. A.S.P.*, **46**, 132), from flash spectra taken without an eclipse, report the presence in emission of the coronal line λ 5303 in the high chromosphere, a region characterized by the great strength of ordinary helium lines. In confirmation of this suggested origin for the coronal lines, it should be recalled that Adams and Joy reported last year on the marked similarity of structure shown by the coronal lines and the ionized helium line λ 4686, as observed in the spectrum of the recurrent nova, RS Ophiuchi. This star, observed again in May (*Pub. A.S.P.*, **46**, 223), shows a reversion to the spectrum observed in 1923 with strong continuous spectrum, strong ionized helium

* Corrected value for 1933.

line λ 4686, and well-marked lines of ionized iron, both forbidden and ordinary, and the complete disappearance of the coronal lines observed in 1933.

In a valuable discussion, which presents new material based on Ludendorff's standardized spectra obtained at the 1923 eclipse, as well as summarizing the earlier work, Grotrian (*Z. f. Ap.*, **8**, 124) assigns the observed continuous spectrum of the corona to two origins. One of these is photospheric spectrum scattered by free electrons, whose velocity of thermal agitation is sufficiently large to obliterate the Fraunhofer lines, and the other behaves like a reflected photospheric spectrum in which the Fraunhofer lines have their ordinary width (see also Moore, *Pub. A.S.P.*, **46**, 298). If such a separation be legitimate (and Grotrian is able to bring forward strong arguments in its favour), it is possible from the intensity ratios of the absorption lines to find the relative contribution of each source to the observed coronal spectrum. From such measures Grotrian finds that the electron-scattered spectrum predominates near the limb, but that its surface brightness decreases rapidly outwards ; the reflected spectrum has roughly the same surface brightness at one solar radius as the electron-scattered spectrum, but increases inwards so slowly that at four minutes from the limb the electron-scattered spectrum is over six times as intense. To find a satisfactory mechanism by which the reflected solar spectrum is produced is not simple, and though Grotrian favours the view that it originates by reflection from solid particles large in comparison with the wave-length of light, he points out that such an hypothesis involves an empty region stretching out to perhaps ten solar radii where such particles would be evaporated, that it requires an essential identification of these particles with those which produce the zodiacal light, and that it has to face the serious difficulty of the large recessional velocity found by Moore.

Observations of the corona without an eclipse form the subject of papers by Skellett (*Proc. Nat. Acad.*, **20**, 461) and by Einarsson (*Z. f. Ap.*, **8**, 208). The former proposes to use a method of television scanning to discriminate between coronal streamers and the steady background of sky illumination. With a 40-inch telescope, and with normal television sensitivity, it should be possible to detect the corona to a distance of about 10 minutes of arc from the limb. Skellett describes some preliminary laboratory trials which would appear to justify some astronomical work.

Chromosphere.—Woltjer (*B.A.N.*, **7**, 217) discusses the diffusion of monochromatic radiation through layers in relative motion, and applies his results to the theory of the solar chromosphere ; the same problem in radiative equilibrium with applications to planetary nebulæ has been discussed by Zanstra (*M.N.*, **95**, 84). In both investigations the effect of relative motion is found to be to make the material more transparent, and consequently to reduce the momentum due to radiation pressure. In earlier papers Woltjer had discussed the lifetimes of excited calcium ions as calculated by Zwaan, and concluded that the chromosphere must have an outward acceleration due to a radiation pressure of 1·38 *g*. Though not explicitly stated by him, it would appear that the investigations of the present

paper must go far towards removing the necessity for supposing the chromosphere to be moving outwards with a large velocity. An extension of his earlier chromospheric theory is given by Chandrasekhar (*M.N.*, **94**, 726), and an interesting discussion of chromospheric theories in general is given by McCrea (*M.N.*, **95**, 80).

Newton (*M.N.*, **94**, 472) gives a statistical survey of the radial velocities of the *Hα* flocculi, measured over the period 1930–33 with the spectrohelioscope at the Royal Observatory, Greenwich. He gives reasons for supposing the large motionless flocculi to be identical with quiescent prominences, and the smaller flocculi, almost invariably associated with sunspots, to be identical with eruptive prominences. This systematic and extended study represents one of the more valuable contributions due to the application of the spectrohelioscope.

Descriptions of various prominences will be found in papers by Keenan, Ruddick and Hickox (*Ap. J.*, **80**, 157, 377; *Pub. A.S.P.*, **46**, 355). While not quite as definitely as might be desired, these papers do give further confirmation of Pettit's suggested mode of prominence motion, namely, periods of constant velocity separated by apparently sharp discontinuities. The prominence observed by Hickox in October attained the unusually great height of 790,000 km., the whole eruptive stage being compressed within a period of one hour.

Absorption Lines and Continuous Spectrum.—Evidence continues to accumulate of the importance to solar physics of the studies of the infra-red solar spectrum initiated by Babcock. Thus Miss Moore and Babcock (*Ap. J.*, **79**, 492) confirm the presence of neutral sulphur in the atmosphere by means of additional identifications in this region of the spectrum, and Moore, Babcock and Kiess (*Ap. J.*, **80**, 59) similarly obtain the first evidence for the presence of phosphorus. King (*Ap. J.*, **80**, 124) gives temperature classes of infra-red iron lines and a number of new identifications of iron in disc and spot spectra. H. D. and H. W. Babcock (*Pub. A.S.P.*, **46**, 132) find the quasi-resonance line λ 10830·3, arising from the metastable level 2^3S of neutral helium, a most suggestive result, and, even more surprising, some evidence for the first line of the Pickering series, λ 10123·9, due to ionized helium.

The possibility that many of the still unidentified lines in the solar spectrum are due to molecules is suggested in an important paper by Russell (*Ap. J.*, **79**, 317). From an equation for the dissociative equilibrium of molecules and his own work on the composition of the solar atmosphere he calculates the relative abundance of the various diatomic molecules, and predicts in particular a greater strength for the hydrides than is observed. He suggests that this may be due to his own estimate of hydrogen abundance being too great, and at the same time points out what a sensitive method this will ultimately prove to be for the determination of hydrogen abundance.

In an important group of papers (*Z. f. Ap.*, **8**, 62; *Observatory*, **57**, 249; Dissertation, Utrecht, 1934) Mulders gives the results of a new calibration of the Rowland intensity estimates in terms of total absorptions, expressed as equivalent breadths. Apart from a relatively sharp discontinuity near

λ 5500, there is for a given Rowland intensity estimate a linear relation of small slope between total absorption and wave-length. This new calibration should prove to be not only of the greatest value for many statistical studies in solar physics, but also, in view of the consistency of the Rowland estimates, it should yield at least a rough value for the total absorption of any solar line. Mulders uses this material to derive a new value of η, the fraction of the total solar energy removed by the absorption lines. He finds the rather low value of 0·083. In a recent paper Shajn (*M.N.*, **94**, 642) finds $\eta = 0{\cdot}14$, the earlier preliminary value of Minnaert being 0·15. The new value of Mulders, particularly in view of his careful revaluation of the solar energy curve, will undoubtedly be accepted as the standard value of this important quantity. The effect of this blanketing by the absorption lines is, as first pointed out by Lindblad, to warm up the layers in radiative equilibrium, and to redistribute the direction of the emergent radiation; for the same effective temperature of the Sun the darkening towards the limb is therefore less than in the absence of absorption lines. Though not given by Mulders, an application of the detailed theory shows that the darkening towards the limb for separate wave-lengths between 3200 A. and 7000 A. is represented better by Mulders's value of η than by $\eta = 0$ or 0·15. The possibility of variation in the total absorptions of Fraunhofer lines is discussed by Minnaert and his colleagues (*Z. f. Ap.*, **8**, 59). A series of measures in 1927, although made without the accurate controls later adopted, revealed an irregular variation of *H* and *K* with a period of three days.

Woolley (*M.N.*, **94**, 631) rediscusses the central intensities of absorption lines, following a suggestion of Pannekoek (*B.A.N.*, **7**, 151). Under dilute radiation detailed balancing breaks down, and, as shown by Rosseland, the cycle 1–3–2–1 preponderates over the opposite cycle 1–2–3–1. The preponderating cycle tends to form emission lines, and, as atoms high up in the solar atmosphere are subjected to dilute radiation, it might be supposed that this "fluorescent" process would tend to yield higher central intensities than the zero value demanded by detailed balancing and the absorption coefficient given by radiation damping theory. After a detailed calculation Woolley finds a central intensity of $r = 0{\cdot}23$ for $H\alpha$; this is revised upwards to $r = 0{\cdot}40$ in a later note (*Observatory*, **57**, 345). It is not made clear by Woolley why his theoretical value is so much larger than the observed central intensity $r = 0{\cdot}15$ (Minnaert), nor in particular why his value is so widely different from Pannekoek's $r = 0{\cdot}05$ found from a theoretical consideration of the same process. In another paper (*M.N.*, **95**, 101) Woolley, using the relation that the sum of the oscillator strengths must equal the valency of the atom, is able independently to calculate the numerical value of the constant in Kramers's absorption law. In the case of hydrogen, exact agreement is obtained between his value and that predicted by Kramers, as revised by Gaunt. In the case of the metallic elements, a mean oscillator strength for the continuous spectrum is calculated on the assumption that the solar coefficient of absorption is the same at 4000 A. and 6000 A. From this mean oscillator strength, and the composition of the solar atmosphere,

Woolley proceeds to calculate the solar absorption coefficient as a function of wave-length. The thus values so computed show little of the independence of wave-length required by the observed darkening towards the limb, and Woolley attempts to account for this discrepancy by invoking the fluorescent process discussed in the earlier paper.

An interesting observation is reported by Meyer, Schein and Stoll (*Nature*, **134**, 535), who, with a monochromator and a sensitive photon counter, have succeeded in recording the solar spectrum at 2100 A. between the Hartley ozone band and the oxygen absorption bands. The intensity of the spectrum, which they have measured as a function of zenith distance, particularly if known relative to the solar spectrum in the ordinary region, will extend knowledge of the energy distribution of the Sun into an exceedingly interesting region.

Limb Effect.—Hunter (*M.N.*, **94**, 594) gives measures of the solar limb effect from two solar rotation plates taken at Edinburgh. He finds a red-ward displacement of +0·006 A., and suggests, on the basis of measurements from the year 1907 onwards, that the limb effect, like the spectroscopically measured solar rotation, varies with time. St. John's hypothesis that the limb effect is due to radially ascending currents, which would give lines from the centre of the disc a violet displacement relative to limb lines, is examined ; this should lead to a variation of the displacement in the form $v \cos \theta$, which neither the measures of Evershed and Royds nor those of Freundlich and his collaborators confirm.

The problem is further discussed in a very significant note by McCrea and Mitra (*Observatory*, **57**, 379). They point out that the equation of continuity requires that the velocity of ascent should vary inversely as the density, and since the optical depth, and so the radial depth, from which the absorption line originates, increases as we pass from limb to centre of the disc, it follows that the velocity v in the expression $v \cos \theta$ must decrease in passing from limb to centre. This is precisely what is observed. Further, by assuming a definite density distribution as a function of depth and a somewhat idealized model of line formation, the two authors are able to reproduce the observed values very closely. Thanks to this note it would appear that the "mysterious" limb effect need be mysterious no longer.

Sunspots.—In an interesting paper F. B. King (*Ap. J.*, **80**, 136) discusses the variation of magnetic field in sunspots as a function of optical depth. On the basis of measures of the plates used for the Mt. Wilson Sunspot Map, King is able to show, though he offers no detailed explanation of the fact, that blending due to scattered light decreases the measured separation of the Zeeman components more for strong than for weak lines. He therefore suggests that the hitherto suspected variation of magnetic field with optical depth may be due to this cause, and by using a selected list of lines with well-marked components and wide theoretical separations he is able to confirm this suggestion. If this view is correct, and observations at the forthcoming maximum should serve to settle this point, a satisfactory theory of the origin of the magnetic field in sunspots will have to account for this negligible variation with height. In connection with such theories,

Larmor (*M.N.*, **94**, 469) gives a more detailed account of his self-exciting dynamo analogy of the sunspot field, and replies to criticisms of this theory made by Cowling.

Nicholson and Sternberg (*Pub. A.S.P.*, **46**, 62, 225) report that the minimum of the sunspot cycle occurred in 1933 November or December, the length of the last cycle being 10·3 years. As at the two previous minima the spots of the new cycle have showed the remarkable reversal of polarity which has been established by Mt. Wilson observations, and which still awaits theoretical interpretation.

The effect in sunspot observations of scattering due to the Earth's atmosphere and to instrumental conditions is discussed by Wanders (*Z. f. Ap.*, **8**, 108). After defining an appropriate scattering function Wanders is able to express the observed profile of a sunspot as an integral equation involving this scattering function and the unknown true profile. Assuming the scattering function can be represented by an error curve law, the standard deviation of this law may be found from observations of the darkening at the extreme limb of the Sun, and with this parameter known for the day of observation the true profile of the spot can be found by a numerical integration. Two less exact, simplified treatments of the same problem are also developed. Using these methods Wanders (*B.A.N.*, **7**, 237) has been able to show that the intensity ratio, spot to disc, is independent of position on the disc, and hence to confirm the suggestion of Minnaert and Wanders that the upper layers of the sunspot are in a condition approximating to radiative equilibrium. H. H. P.

Stellar Spectroscopy

Instruments and Methods.—J. Weigle (*Pub. Obs. Genève*, **4**, 5) has described a new form of self-registering microphotometer specially designed to be less costly than most of such instruments at present on the market. The chief difference lies in the fact that the printing paper remains fixed, while the galvanometer is caused to rotate as a whole in conjunction with a motion of the plate carrier, several different rates of rotation being available. Galvanometer deflections take place round an axis at right angles to the axis of the above rotation. The accuracy of correlation of plate movement with horizontal deflection of the galvanometer beam rests simply on a geometrical relation and is independent of the precision of screw threads or other mechanical parts—an arrangement which assists in cutting down the cost of manufacture. A new microphotometer has also been designed by Plaskett (*M.N.*, **95**, 160), in which particular attention has been paid to proper collimation of the optical parts and to achieving accuracy in the correlation of intervals on the tracing with intervals on the plate. Plaskett in addition gives details of useful tests for assessing the efficiency of a microphotometer with regard to resolving power, accuracy of reproduction, etc.

P. Rossier (*Pub. Obs. Genève*, **4**, 16) suggests the use of an objective

prism in place of the usual coarse grating for the measurement of effective wave-lengths. With a direct-vision prism of a diameter smaller than the diameter of the telescope, a direct stellar image would be produced together with one displaced image (spectrum), the distance between which would give effective wave-lengths in a manner analogous to that when a grating is used. There would, however, be great gain in the brightness of the second image, and the separation might even be measured visually with a micrometer like a double star in addition to photographically.

The effect of instrumental constants, such as dispersion and resolving power, on observed line contours has been studied by P. Th. Shajn (*Pulk. Obs. Bull.*, **13**, No. 4) by comparing contours of selected lines obtained with spectrographs of various dispersions. He has found that in the case of wide isolated lines, such as the helium line at 4026 A., there is practically no difference between results obtained with widely differing dispersions. The contour is only slightly affected by instrumental causes. In the case of narrow lines, however, the central absorption decreases and total absorption increases with decreasing dispersion. This is possibly the principal reason for systematic differences between contours of the same lines obtained at different observatories.

Investigations in the Red and Infra-red.—The recent production of commercial photographic plates sensitive to infra-red light is an asset to stellar spectroscopy of which considerable use has already been made. A photographic reconnaissance of stellar spectra in the near infra-red (7000–9000 A.) has been made by Merrill (*Ap. J.*, **79**, 183). He finds the chief infra-red lines in α Cygni to be due to *H*, *N*I, *O*I, *Mg*II and *Ca*II. The Paschen series of hydrogen is also conspicuous in this and other A-type stars, especially those with "c" characteristics. The *O*I lines are still conspicuous in F-type stars. In classes K and M the lines of neutral *Ca*, *Ti* and *Fe* are very pronounced, with many *TiO* bands in the latter class, while the complex structure observed in N-type stars is shown to be due to cyanogen absorption. Merrill, with O. C. Wilson (*Ap. J.*, **80**, 19), has also made a comparison of the structure of the Paschen and Balmer lines in stellar spectra. Most of the Paschen lines have contours of simple exponential form, except in the broad-line stars such as α Leonis and α Lyræ. In the sharp-line stars, and also the Be stars γ Cassiopeiæ and P Cygni, the Paschen lines are similar in shape to those of the Balmer series, but the central intensities are in general less than those of the corresponding Balmer lines.

Roach (*Ap. J.*, **80**, 233) has made a study of stellar spectra in the region 6562–7593 A. In Procyon, Arcturus, Aldebaran and Betelgeuse he has measured 426 lines, a large number of which have been satisfactorily identified. Iron contributes the largest number of lines (150), followed by *Ti* (29) and *Zr* (24). The following elements are also definitely present: *H*, *Al*, *Si*, *S*, *Ca*, *V*, *Cr*. In Vega and Sirius 33 lines (mostly weak) were measured in this region.

Öhman's (*Ap. J.*, **80**, 171) spectrographic studies in the red region up

to 7600 A. deal mainly with luminosity effects, and are referred to under the heading "Spectroscopic parallaxes."

The necessity for accurate wave-lengths in the spectrum of some convenient source which can be used as a standard comparison in these regions is becoming increasingly evident. A step has been made in this direction by Dingle (*M.N.*, 94, 866), who has measured the wave-lengths of 68 iron lines between 8838 A. and 10219 A. The spectra were obtained in the first order of a 10-foot concave grating, using overlapping second and third order spectra as comparisons for determining wave-lengths. The results are not proposed as ultimate standards but are probably correct to within 0·01–0·02 A.

Bright-Line Stars.—The value of the intensity gradient of the hydrogen emission lines in Be-type stars has an important bearing on the theory of the formation of such lines. This has been measured by Karpov (*L.O.B.*, No. 457) in the case of 36 stars of types O9 to A0, and he has found that the gradients agree well with the values theoretically predicted on the assumption that the emission lines are formed by a process of recombination of ionised hydrogen atoms with free electrons (a process already suggested as an explanation of the spectra of planetary nebulæ). The continuous emission at the end of the Balmer series was also measured and found to be approximately six times as strong as the corresponding $H\alpha$ emissions—an intensity much greater than that predicted by theory, though it is possible that the latter value may be too small.

Van Arnam (*Ap. J.*, 79, 140) has found that the contours of Balmer lines in κ Draconis show no correlation between intensity of emission and width of absorption wings, thus suggesting that these lines originate in different layers in the star in accordance with Struve's rotational hypothesis of the origin of bright lines.

A reinvestigation of the absolute magnitudes of Be stars has been made by McLeod (*H.B.*, No. 894, p. 1), using proper motion and cluster data. He finds Gerasimovič's previously determined values to be considerably too bright, and concludes that Be stars in the average are not more than 0·4 mag. brighter than normal B-type stars. The dispersion in luminosity, however, is large; and those of type cBe are amongst the most luminous stars in the sky, ranging up to $-5{\cdot}3$ absolute magnitude. Gerasimovič (*H.B.*, No. 897, 6) has re-examined McLeod's data. From this and other sources (such as distances from interstellar calcium line intensities) he finally adopts $\Delta M = -1{\cdot}5$ as the best possible value for the difference, Be stars—normal B stars.

Merrill (*Ap. J.*, 79, 343) has investigated the spectrum of H.D. 33232, a Be star which appears to combine features ordinarily found in different types, and to possess other puzzling characteristics. The helium lines and *Mg* 4481 resemble the typical B3n spectrum, whereas the intense sharp hydrogen absorption and narrow ionised iron and silicon lines suggest "c" characteristics in type A0. Radial velocities from hydrogen lines give the very long period of 3710 days. The iron, silicon and magnesium lines

show greater amplitudes of variation than that found from the hydrogen lines, while the phases appear to be earlier.

Spectroscopic Parallaxes.—Lindblad and Stenquist (*Astr. Jaktt. Stock. Obs.*, **11**, No. 12) have reinvestigated the spectroscopic criteria of stellar luminosity in very small dispersion objective-prism spectra. The most useful luminosity effects visible in such spectra are in the intensities of the hydrogen lines and cyanogen bands. The results are not so accurate as those from other spectroscopic parallax methods, but they are useful for statistical purposes and for segregating physically defined groups of stars within close limits of absolute magnitude. The great advantage of the method lies in the possibility of dealing with large numbers of faint stars. Similar materials and methods are used by Ramberg (*Astr. Iaktt. Stock. Obs.*, **11**, No. 13) in a study of the Hyades. He uses, in addition, the intensity of the calcium line at 4227 A. as a criterion of luminosity, and gives the results for 11 scattered late-type dwarfs from plates taken by Lindblad as well as for 21 stars in the Hyades group.

E. G. Williams (*Pub. A.S.P.*, **46**, 292) has found some interesting luminosity effects in B-type stars, through photometric measurements of absorption line intensities in the spectra of stars of Struve's giant and dwarf groups. In the case of hydrogen the total absorption appears to be nearly constant for giants of all spectral types, whereas for dwarfs it increases rapidly from O to B8. The helium lines are stronger in dwarfs than in giants, while the reverse effect is observed in the lines of *Mg*II, *O*II, *N*II, *C*II and *Si*II and III.

A study of representative stars in the orange and red regions of their spectra by Öhman (*Ap. J.*, **80**, 171) has yielded some good criteria for distinguishing giants from dwarfs in stars of type M. He has found that three bands of *CaH* at 6389-6382 A., 6921–6903 A. and 7305–7208 A. occur conspicuously in dwarf spectra but are weak or absent in giants. In addition the spectra of dwarfs appear smoother than those of giants on account of the presence of much stronger *TiO* bands in the latter. Miss Burwell's results for the calcium lines 6162 A., 6122 A. and 6102 A., all of which are very strong in dwarfs but faint or invisible in giants, are confirmed.

Merrill (*Ap. J.*, **79**, 183), in his work on infra-red spectra already referred to, has found the *O*I lines at 7772–5 A. and 8446 A. to be very sensitive to absolute magnitude, being more intense in the brighter stars.

J. S. Hall (*Ap. J.*, **79**, 145) has suggested the possibility of determining absolute magnitudes of giant stars, later than type F8, from their colour excesses in the infra-red.

Distribution of Energy in the Continuous Spectrum.—On the observational side, Greaves, Davidson and Martin (*M.N.*, **94**, 488) have rediscussed the zero point of the Greenwich colour temperature system. Their procedure has been improved at several points, notably in the substitution of a tungsten filament lamp for an acetylene burner as laboratory standard. For a group of Ao stars the average $\phi_0 = 1{\cdot}0$, *i.e.* the mean temperature is 18,000° K, a

remarkable value in view of the temperature of 11,000° accepted for these stars until very recently. As far as can be ascertained, it is very improbable that the error in ϕ_0 exceeds 0·15, or, in other words, that the mean Ao temperature lies outside the range 14,000°–24,000°.

Theoretical investigations have shown that in certain circumstances the colour temperature derived from light integrated over the whole star disc may be considerably different from the true temperature of the stellar atmosphere itself. Kosirev (*M.N.*, 94, 430) has shown that if a hot star has a very extended atmosphere the colour curve of the visible spectrum will correspond to a much lower temperature than would be found if observations could be made in the far ultra-violet. The possibility presents itself of explaining the yellowness of certain early type stars without recourse to interstellar absorption. Unsöld, on the other hand, has demonstrated the possibility of a difference in the opposite direction between colour temperature and effective temperature (*Z. f. Ap.*, 8, 32). He obtains this result from an examination of the general problem of a stellar atmosphere composed entirely of hydrogen.

Molecular Spectra.—The behaviour of *ZrO* in M-type stars has been investigated by Bobrovnikoff (*Ap. J.*, 79, 483). The search was confined to the red region of the spectrum in which the bands of lowest excitation potential occur, since only these are strong enough to appear in low-dispersion spectrograms. He found 20 *ZrO* bands in the spectrum of β Pegasi ; the strongest band, at 6473·7 A., being specially strong in this star and in ρ Persei. The author attributes this to unusual abundance of *ZrO* in the atmospheres of these stars.

Swings (*Medd. Stock. Obs.*, No. 15) has investigated the behaviour of *SiF* bands in stellar spectra. The results from eight stars of different spectral types indicate that the number of *SiF* molecules increases continuously with spectral type from Go to M, but that this increase is much slower than in the case of *TiO*.

Russell (*Ap. J.*, 79, 317) has discussed theoretically the question of molecules in Sun or stars, following methods analogous to those used earlier by him for atomic spectra. The behaviour with regard to temperature and absolute magnitude of bands of such compounds as *TiO*, *CH*, *CN* agrees well with observation. The predicted properties of stars with an excess of carbon over oxygen resemble those of stars of types *R* and *N*.

Problems relating to the dissociation of molecules in stellar atmospheres have been discussed by Wurm (*Z. f. Ap.*, 9, 156) and by Wildt (*Z. f. Ap.*, 9, 176). The former inquires into the possibility of formation of emission hydrogen Balmer lines by excitation of hydrogen *molecules*. Wildt, taking into account dissociation of the molecules, shows that the ratio κ' of apparent specific heats in hydrogen at low temperatures (1000°–5000°) can be less than the critical value 4/3. In consequence, one may expect turbulence to be present in the atmospheres of M-type stars, within certain ranges of temperature and pressure, and to have an important influence on their spectra.

Interstellar Matter.—The distribution of the light-scattering material which gives rise to colour excesses in more distant stars has been discussed by E. G. Williams (*Ap. J.*, **79**, 273) by comparing colour excesses of B-type stars with the intensities of their interstellar [K] lines and assuming the approximate uniformity of the interstellar calcium clouds. The total absorptions of the [K] lines were measured in 67 stars with probable errors of about 5 per cent. and compared with colour excesses (obtained from three different sources and corrected for absorption by the Balmer lines). There appears to be a statistical correlation between these quantities, but the considerable dispersion indicates that the scattering matter is not co-extensive with the calcium. The bright-line stars are all too red for their distances—a fact which may have some bearing on Struve's theory of their origin, which would explain this effect by an atmosphere of scattering matter ejected from rapidly rotating stars.

Struve (*Ap. J.*, **78**, 273) has suggested that the possibility of condensations in the general interstellar cloud may be inferred from a comparison of distances as determined from the galactic rotation effect and from the intensities of interstellar calcium lines. From a statistical study of the data in the Victoria Catalogue he finds two regions (in Cepheus and Auriga) which suggest calcium condensations, and two others (in Cygnus and Perseus) which appear to show opposite effects.

Beals (*M.N.*, **94**, 663) has measured the total intensities of interstellar lines in the spectra of early-type stars in the clusters *h* and χ Persei. Differences in intensity occur between different stars in the same cluster which can scarcely be caused by varying distances, and the author suggests a blending with stellar calcium lines as the most reasonable explanation. His previous results on the relative intensities of interstellar calcium and sodium lines are confirmed; the latter being considerably stronger than the former in the majority of stars.

The number of stars of late spectral type in which interstellar lines have been observed continues to increase. The most promising stars are very distant eclipsing binaries with velocities high enough to separate the stellar from interstellar lines. Joy (*Pub. A.S.P.*, **46**, 51) has examined the three stars WY And, AG Aur and UU Her from this point of view, and found very strong interstellar sodium lines (D1 and D2).

Four new lines at wave-lengths 5780·4, 5796·9, 6283·9 and 6613·9 A. have been discovered by Merrill (*P.A.S.P.*, **46**, 206) in spectra of types Oa to A4. With regard to occurrence, intensity and displacement they behave like the ordinary interstellar lines of calcium and sodium, but, unlike the latter, are rather wide and diffuse. Identifications have not been found.

Radial Velocities.—Harper (*Pub. Dom. Ap. Obs.*, **6**, No. 10) has published the radial velocities of 477 stars of types F to M from plates taken with the single-prism instrument attached to the 72-inch reflector at Victoria. No previous velocities had been determined for 113 of these stars, including eight spectroscopic binaries. Comparisons with Moore's General Catalogue

show that the Victoria results are, in the average, 0·9 km. more negative than the catalogue values, but the cause of this discrepancy remains obscure.

The radial velocities of 343 stars have been published by Albitzky and Shajn (*Pulk. Obs. Pub.*, Ser. II, vol. xliii), using the new 40-inch Simeis reflector. They include stars of most spectral types, but the greater number are Fo to F8, and the visual magnitudes range down to about 6·5. Systematic errors were investigated through 42 stars which are given in Moore's Catalogue. Corrections necessary to reduce to the Lick system were found to be −0·5 km./sec. for stars of types G to M, and −0·1 for types B8 to F8.

Albrecht (*Ap. J.*, **80**, 86) has continued his work on accurate stellar wave-lengths, aiming at giving for each of a series of standard stars the wave-lengths of as many lines as possible with an accuracy which will be of great value in radial velocity work on stars of similar spectral types. His latest study is of Procyon (type F5 dwarf), for which wave-lengths of 1094 lines are given to 0·001 A. The probable errors, intensities, widths and identifications (where possible) are also given, together with all data which would be necessary if a future rediscussion of wave-lengths should be desirable. The radial velocity of Procyon, according to this work, is variable with a short period and an amplitude of the order of 10 km./sec. Schaub (*Z. f. Ap.*, **9**, 198), however, has put forward reasons to show that this is erroneous and quotes long series of observations made at Bonn and at the Cape, which give no sign whatever of this velocity variation.

Miscellaneous.—Beals (*Pub. Dom. Ap. Obs.*, **6**, No. 9) has continued his important work on the spectra of Wolf-Rayet stars. His theory of the continuous ejection of atoms from the stellar surface would explain any symmetrical band contours if a suitable frequency distribution of the velocities of ejected atoms is also postulated. Flat-topped contours would result when there are no velocities in the vicinity of zero. Such contours, though found in novæ, are exceptional in the case of Wolf-Rayet stars, thus indicating a different frequency distribution of velocities of ejected matter in the latter stars. The classification of Wolf-Rayet spectra has had to be modified. It appears that they may be divided into two sequences, characterised by ionised carbon and ionised nitrogen respectively. These sequences are approximately parallel as regards ionisation level, and the presence of both *He*I and *He*II in each of them has hitherto masked their separate characters. Temperatures, computed by Zanstra's method, are found to range from 50,000° to 100,000°, with no apparent differences either in range or general level between the two sequences.

The simple theory given by Beals for the distribution of light within a Wolf-Rayet band has been modified by Chandrasekhar (*M.N.*, **94**, 522) to take account of the occultation of a part of the expanding shell by the parent star. The result is an unsymmetrical band, but there appears to be difficulty in confirming this observationally, on account of asymmetry arising from absorption which is very frequently encountered on the violet side of the band. This difficulty is particularly serious in the case of P Cygni (Beals,

Observatory, **57**, 378) where the occultation effect might otherwise be expected to be most marked.

Struve's work on the wave-lengths, origins and behaviour of lines in the spectra of B-type stars has been extended by Marshall (*Pub. Obs. Mich.*, **5**, No. 12) mainly in the near ultra-violet. The spectra of 11 stars (the same as those discussed by Struve, with one exception) have been measured over the range 3587–5047 A. Intensities, atomic symbols (when identified) and laboratory wave-lengths are given for 534 lines in this region. Half of these lines have not yet been identified, and only about two-fifths of the remainder are regarded as satisfactorily identified. Some additional identifications have been made by Swings and Nicolet (*Ap. J.*, **80**, 190). Their list includes about 50 lines for which no previous identifications had been made. 21 lines of *Ne*II have been identified in τ Sco (type B0) by Kühlborn (*Z. f. Ap.*, **8**, 190). Some of these identifications have been criticized by Swings and Nicolet (*Z. f. Ap.*, **8**, 370; see also Kühlborn, *ibid.*, **8**, 372).

Christine Westgate (*Ap. J.*, **79**, 357) has extended her statistical studies of rotational broadening to the F-type stars. The width of *Sr*II, 4215 A., was recorded for 112 stars of this class. The results appear to indicate that appreciable rotation disappears rather suddenly between F2 and F5, and that A-type stars have greater rotational velocities than either B- or F-type stars. No definite relation seems to exist between rotational velocity and absolute magnitude.

Accurate wave-lengths of ionised silicon lines (*Si*II, III and IV) which occur in early-type stars have been measured interferometrically by C. V. Jackson (*M.N.*, **94**, 723), using secondary standards of krypton as a comparison. Wave-lengths of 10 lines are given with a probable error of $\pm$ 0·001 to $\pm$ 0·002 A. D. L. E.

Stellar Motions

Galactic Rotation.—The methods of Mineur which were mentioned last year are applied by Mineur and Guintini in a profusely illustrated paper to the space-motions of the B stars (*B.A.*, **8**, 227). The systematic velocities are in reasonable conformity with Oort's hypothesis, although the use of a general expression containing numerous adjustable constants naturally produces a still better representation. The authors find no significant variation of systematic velocity with distance from the galactic plane. Further results are given by Mineur in *C.R.*, **198**, 1389, 1578. He finds that the motions cannot be completely represented by rotation depending only on distance from a fixed centre, and analyses them into rotational and expansive parts. The space-motions of 527 A stars are listed and discussed by Bertaud in *B.A.*, **8**, 337. As these stars are mainly within 100 parsecs, the results for apex and vertex are more certain than those for galactic rotation. The elimination of the Taurus and Ursa Major clusters changes the longitude of the vertex from 351° to 359°. The velocity-ellipsoids of G, K and M stars are considered by Mineur and Camichel in *C.R.*, **199**,

262. The variation with position in the galactic plane is found to be too slight to give a determination of the longitude of the galactic centre.

Edmondson investigates in *A.J.*, **43**, 92, the dependence of solar velocity on the mean parallax of the stars considered. He finds a displacement in the same direction as Mineur's suspected drift, though of a different character, and tends to interpret it as due to rotation of the local cluster. It is, however, contended by J. M. Mohr in *A.J.*, **44**, 15, that Edmondson's results are compatible with Oort's hypothesis.

In *P.A.S.P.*, **46**, 227, Sanford discusses his radial velocities of no fewer than 146 stars of class N. They appear to show fairly normal galactic rotation and a mean absolute magnitude, allowing for absorption, of about $-2{\cdot}2$ visual. The velocities of interstellar calcium about 1000 parsecs away are found by Struve in *Ap. J.*, **79**, 273, to show no measurable "second-order" galactic rotation, so that the galactic centre is probably not less than some 10,000 parsecs distant. A query by Edmondson (*A.N.*, **251**, 45) is answered by Bertaud (*ibid.*, 189).

The important researches of J. S. Plaskett and Pearce are continued in a paper (*M.N.*, **94**, 679) in which final values of Oort's constants are derived from the radial velocities and proper motions of O and B stars. The work involves consideration of the southern stream of B stars and a determination of precessional corrections by Oort's method. The authors find a distance of about 10,000 parsecs to the galactic centre ; there is no doubt that the discrepancy between the kinematical and distributional determinations of this important quantity is less serious than it once seemed.

The year has brought forth a considerable amount of work on the dynamics of the galaxy. A general investigation of the distribution-function in a restricted region for a restricted time is given by Heckmann and Strassl (*Nachr. Ges. Wiss. Göttingen*, Math.-Phys. Kl., Fachgruppe II, Neue Folge, **1**, 91). The motions parallel and perpendicular to the galactic plane are assumed to be independent ; thus the work is similar as regards its short-time outlook to that of Oort mentioned last year, and velocity-ellipsoids with three distinct axes naturally occur. Further developments and applications of the theory are in prospect.

The evolution of rotating stellar systems is discussed by Lindblad in two papers (*M.N.*, **94**, 231 ; **95**, 12) on the part played by inelastic collisions and loss of fast-moving stars in helping to establish a highly flattened system. Strömberg, on the other hand, tends to consider the flattening as an effect of viscosity in the earlier nebular stage (*Ap. J.*, **79**, 460, *M.W.Ct.* 492 ; *Ap. J.*, **80**, 327, *M.W.Ct.* 503). There would seem to be an abundance of reasons why a three-dimensional system with angular momentum might gradually develop into something like the galaxy as now conceived, namely, an enormous concentration of matter towards a diametral plane of a nearly spherical system. It need hardly be added that investigations of the above kind are closely related to those (outside the scope of this Note) on the structure of extra-galactic nebulæ.

Apex and Vertex.—The results of some 25 years' work at the Radcliffe Observatory are published in *The Radcliffe Catalogue of Proper Motions*

in the Selected Areas 1 *to* 115, by Knox-Shaw and Barrett. This contains accurate proper motions with a mean interval of 13·4 years for over 32,000 stars down to about the fifteenth magnitude. The material is discussed in the preface and in papers by Knox-Shaw (*M.N.*, **94**, 399; erratum, 677) and Barrett (*ibid.*, 782). It is found that the apex for such faint stars (unless selected by proper motion) tends to be merely a reproduction of that assumed in converting the proper motions from relative to absolute. A determination of the vertex by Schwarzschild's method gives a normal result. An important observational publication is the catalogue by Hins in *Leiden Ann.*, 15 (4), of meridian positions of 1190 stars in Areas 2 to 115, based on observations at Leiden, Babelsberg, Bonn, Paris and Strasbourg.

The velocity-distribution of A stars is discussed by Robb in *M.N.*, **94**, 406, and an extensive investigation of the frequency-distributions of motions and magnitudes is made by Gyllenberg in *Lund Medd.* (2) 68. The latter includes details useful for a division of the sky into 96 equal areas. The vertex is determined graphically from 1937 space-velocities by Klumak (*A.N.*, **251**, 185). In *Russ. A.J.*, **11**, 40, Vorontsov-Velyaminov discusses, *inter alia*, the radial velocities of planetary nebulæ.

Photographic proper motions in several regions are analysed into streams by Miss White (*M.N.*, **94**, 783) and Bemporad (*Lincei Rend.* (6), **18**, 177, 425). Solutions for parallactic motion from the stars of the San Luis catalogue are given by Tucker (*Pop. Astr.*, **42**, 6).

Some peculiarities in the distribution and motions of the stars within 15 parsecs are pointed out by Haas in *A.N.*, **251**, 193. Luyten reports in *P.A.S.P.*, **46**, 194, on the proper-motion survey, by blink microscope, of the southern sky. A great increase in known large proper motions has resulted; for instance, the number of known proper motions greater than $0''{\cdot}5$ annually in the region surveyed has been increased from 30 to 156. See also Luyten, *M.N.*, **94**, 193.

Moving Clusters.—An extensive investigation into the stability of moving clusters is given by B. J. Bok in *H.C.* 384. The older work requires revision on account of the discovery of galactic rotation. Bok finds that a cluster in our neighbourhood needs a minimum density of 0·093 solar masses per cubic parsec if it is to withstand the tidal forces due to the gradient of the galactic field. Even such a stable cluster will eventually be disrupted through the effect of random encounters, which Bok also studies. The theory is applied to several well-known clusters. The author remarks that the rate of growth of the Taurus cluster does not exceed a few tenths of a km./sec. at any stage of its development. An upper limit of about 2×10^{10} years is obtained for the age of the galaxy.

Mlles Canavaggia and Fribourg find in *C.R.*, **199**, 777, that the Ursa Major, Taurus and Scorpio-Centaurus clusters exhibit galactic rotation with very unusual values of the constants. The probable errors are considerable, however, owing to the comparatively small extension of the clusters in space. From the dispersion of the best photographic proper motions Hertzsprung concludes that the internal motions of the physical members of the Pleiades (eliminating change of scale and rotation about the

line of sight) are of the same order as the errors of observation, namely, about 0″·001 annually (*B.A.N.*, **7**, 187). Internal motions in clusters are considered by Larmor (*Obs.*, **57**, 23).

New members of the Taurus cluster are found by van Rhijn and Raimond (*M.N.*, **94**, 508), W. C. Martin (*B.A.N.*, **7**, 168) and Bertaud (*B.A.*, **8**, 337). Members of the Ursa Major cluster are picked out by Nassau and Henyey (*Ap. J.*, **80**, 282) from the Yale *Catalogue of Bright Stars*, and by Bertaud (*B.A.*, **8**, 109) from his computed space-velocities of A stars. Most of the above workers allow a difference of about 10 km./sec. between computed and observed motion.

Mean Parallaxes and Luminosities.—In *Lund Medd.* (1) 138, Gyllenberg derives the dispersion in absolute magnitude for various groups from the skewness and excess of the distribution of the observed proper motions in the Lund A.G. zone, on the assumption that the linear velocity-distribution is Gaussian.

Photographic proper motions for 33 planetary nebulæ are derived and discussed by C. M. Anderson in *L.O.B.*, **17**, 21. The mean parallax of 0″·0007 agrees closely with that obtained for 21 objects by van Maanen. Elements of motion and mean absolute magnitudes are evaluated for three groups of Oe and Be stars by McLeod (*H.B.* 894), while the F5–G5 stars, which are particularly amenable on account of the large percentage of dwarfs, are discussed by Schilt in two papers (*A.J.*, **43**, 121, 193). The luminosities of the K stars are further considered by Gratton in *M.N.*, **94**, 467.

The proper motions of the short-period Cepheids are discussed by Fletcher in *M.N.*, **95**, 56. The residuals from the parallactic motion are found to be considerably larger than the cross proper motions, so that the determination of a mean parallax is rather difficult, quite apart from any uncertainty in the radial velocities. Although the solar and peculiar motions are very large, it is desirable to correct for galactic rotation ; but the correction would at the moment be somewhat conjectural, as the principal observational evidence for galactic rotation relates to radial velocities and low latitudes. Some comments on the relative importance of meridian and photographic proper motions for a determination of the Cepheid zero-point are made by Luyten in *Obs.*, **57**, 101. In *Russ. A.J.*, **11**, 95, Parenago derives meridian proper motions for 16 RV Tauri variables, and deduces a mean absolute magnitude of $-0{\cdot}6$.

J. M. Mohr discusses in *A.J.*, **44**, 10, the conditions under which Edmondson's simplified mean-parallax formula may be used, with numerical illustrations from various groups of stars. Edmondson's formula has recently been subjected to a thorough mathematical investigation by Smart (*M.N.*, **95**, 116) on the basis of the two-streams theory. It appears that the formula can be exactly established, two errors in its original derivation having cancelled one another. The use of the formula should save a very great amount of labour in computing mean parallaxes for groups containing numerous stars distributed over the whole sky. The computational technique of transformation of proper motions is the subject of a note by Edmondson in *A.N.*, **251**, 217.

A. FL.

Variable Stars, 1934

This survey is restricted to work actually published in 1934.

Theoretical.—Milne (*M.N.*, **94**, 418)* gives a powerful method of analysing stellar variability, consisting in plotting the logarithm of the radius of the star against the logarithm of the luminosity. During a cycle of variation the star describes a closed curve on this diagram. Although the method was developed with reference to Cepheids it has general application. Milne enumerates various theoretical points brought out by these diagrams. A paper by T. E. Sterne (*Harv. Circ.* 386) suggests that the existence of random errors of sampling in the cycles of a variable star prevents the inferences of true changes of period from comparison between observations and computed magnitudes. Many supposed changes of period are simply statistical fluctuations. For example, RR Scorpii has a period $279^{d}\cdot44 \pm 0^{d}\cdot44$ from 1846 to 1933, and, contrary to previous announcements, there is no evidence of variability in the period. A number of actual light curves of variable stars are analysed according to this method by I. A. Getting (*M.N.*, **95**, 139).

Cepheid Variables.—Modern light curves of δ Cephei (1927–1932) and η Aquilæ (1928–1932) are published by McLaughlin (*A.J.*, **43**, 113 and 129 respectively), and a rediscussion of the period of X Sagittæ by Hertzsprung will be found in *B.A.N.*, **7**, 191. The important question of the zero-point of the mass-luminosity relation has been discussed by Gerasimovič (*Obs.*, **57**, 22), Luyten (*Obs.*, **57**, 101), Fletcher (*M.N.*, **95**, 56) and Nassau (*A.J.*, **44**, 33). The first three mentioned concern themselves with the bearing of the proper motions of short-period Cepheids on the zero-point, but Nassau assumes a definite zero-point for the period luminosity law and computes parallaxes which he compares with observed values. When no correction is applied to Shapley's zero-point, the differences 'observed minus computed' agree with a Gaussian error curve.

Eclipsing Binaries.—R. S. Dugan has published a "Finding List for Observers of Eclipsing Variables." This list should be of considerable help in making up an observing programme, visual, photographic or spectroscopic (*Contr. Princeton Univ. Obs.*, No. 15). The well-known star β Lyræ has received some attention this year from a number of writers. Miss Pillans (*Ap. J.*, **80**, 51) has published a note on the spectrum, and the late Professor R. H. Curtiss (*Pub. Obs. Mich.*, **5**, 177) has published visual observations of the magnitude of β Lyræ extending from 1913 to 1920. Two articles appeared in *The Observatory*, **57**, by Stratton, on p. 163, and by Struve, on p. 265. Both are comments on theoretical interpretations, which have been brought forward to account for the observations. McLaughlin (*Pub. Obs. Mich.*, **6**, 3) investigates the effect of axial rotation on the radial velocities of Algol, λ Tauri and δ Libræ. Dimensions of these binaries, and of the system RZ Cassiopeiæ, are given. The same author

* See also a paper by Milne in *Quarterly Journal of Mathematics*, **4**, 258, 1933, referred to in *Obs.*, **57**, 137.

publishes (*Ap. J.*, **79**, 235) a discussion of the spectrum of ϵ Aurigæ. Other eclipsing variables that have been discussed this year are 62·1933 Lacertæ, by Uitterdijk (*B.A.N.*, **7**, 159), and a new eclipsing binary which has a remarkable eccentricity, C.P.D. $-29°$ 5846, by Ferwerda (*B.A.N.*, **7**, 165). Finally a very extensive study of the star ζ Aurigæ has been carried out during its recent eclipse in 1934 September by a number of observatories. The only observations which have yet been published are those made at Cambridge. Smart and Green (*M.N.*, **95**, 31) describe a series of observations of the magnitude of the system during eclipse by comparison with η Aurigæ with a photoelectric photometer. The probable error of their determinations is $\pm$ $0^m{\cdot}004$. Spectroscopic observations have been carried out at the Solar Physics Observatory with the Newall telescope. These are described by Beer (*M.N.*, **95**, 24). The system has a peculiar interest since it consists of a K super-giant and a B star, so that it is the first to give the dimensions and mass of a red super-giant directly from observation. A further point of interest is the appearance of the Ca^+ K line in the B spectrum when the latter is seen through the extended atmosphere of the K star.

Novæ.—Chandrasekhar (*M.N.*, **94**, 522) discusses the theoretical contours of emission bands in nova spectra to be expected as a consequence of the hypothesis of radial ejection of the atoms in an expanding shell, which give rise to the bright bands. He calls attention to an occultation effect which will give rise to marked asymmetries in the contours of the bands. O. C. Wilson (*Ap. J.*, **80**, 259) describes a method by which the velocity gradient in an expanding shell can be found from analysis of the band contour. He applies this to RS Ophiuchi. The year has been unusually rich in observations of novæ, chiefly on account of the appearance on 1934 December 13 of a naked-eye nova in Hercules. Numerous communications of a preliminary nature have appeared in the *A.N.* and elsewhere, but naturally no definitive publications have appeared in 1934. We may, however, summarise the preliminary results given in the *A.N.* and elsewhere by remarking that the nova when discovered by Prentice had a visual magnitude of $2^m{\cdot}9$, and declined to a minimum of $3^m{\cdot}4$ on December 15. After this date the magnitude rose to $1^m{\cdot}3$ on December 23, since when there have been sharp fluctuations. On December 13, at the time of discovery, the nova exhibited a spectrum of P Cygni type, showing *H* and *He*. On December 15 Fe^+ became prominent. On December 20–23 the spectrum became almost devoid of emission lines, and corresponded line for line with that of α Cygni (*c*A2*p*). After the maximum brightness on December 23 the absorption spectrum gave way to an emission spectrum. The nova has been identified with a star of magnitude $15^m{\cdot}4$ on the Franklin-Adams plates. There is some evidence tending to show that the nova was a variable before the present outburst.

H. S. Jones (*M.N.*, **94**, 816) describes the spectrum of RR Pictoris in 1934 as being similar to that of 1933, namely a strong continuous spectrum overlaid with diffuse emission bands. The author is able to explain some peculiarities in the presence and absence of certain members of an

*O*III multiplet along lines developed by Bowen to account for similar behaviour of the lines in planetary nebulæ (*L.O.B.*, 459). O. C. Wilson and E. G. Williams (*Ap. J.*, **80**, 344) publish an account of spectrophotometric observations made at Mt. Wilson on the nova RS Ophiuchi. Although these observations were not made under ideal photometric conditions, the results obtained, being the first of the kind ever published, are a check on nova theory. The Balmer series emission bands show no signs of a flat-topped contour, and the colour temperature of the continuous spectrum is 4000° on the Greenwich system. These authors deduce a distance of 920 parsecs from the strength of the interstellar Ca^+ lines. This gives the nova an absolute magnitude of $-5{\cdot}6$ at maximum.

W. H. Steavenson (*M.N.*, **95**, 78) draws attention to the existence of a star of about $15^m{\cdot}5$ close to the reputed position of Nova Vulpeculæ (1670). There is evidence of variability and of some spectral peculiarity in this faint object, and it is concluded that there is some probability of its identity with the nova.

B.A.A. Variable Star Memoir.—During the year the eleventh *Report of the Variable Star Section of the British Astronomical Association* (*J.B.A.A.*, **31**) has been published. It contains 59,938 observations of 51 long-period variables made by fifty-one members of the Section during the years 1925 to 1929. R. v. d. R. W.

Double Stars

New Pairs.—In *P.A.S.P.*, **46**, 188, 235, 285, and 287, Kuiper publishes respectively : 14 new pairs ; 2 new close M-dwarf binaries of large parallax ; 5 new pairs, 4 of which have large parallaxes ; 2 new bright pairs, one of which has a composite spectrum. These discoveries were made with the 12-inch Lick refractor.

Milburn gives 106 new pairs in continuation of his earlier lists (*M.N.*, **94**, 255). Barton continues his selection from the astrographic catalogues, pairs 1135–1164 from Helsingfors (*A.J.*, **43**, 119).

Luyten gives a second list, pairs 103–193, of faint wide pairs with common proper motion (*M.N.*, **94**, 191).

A faint physical companion to ϵ Cyg is noted by van Maanen (*P.A.S.P.*, **46**, 296). BD $+7°2031$ is found by van de Kamp to be a faint common proper motion pair (*P.A.S.P.*, **46**, 139).

Measures.—Giacobini publishes measures of 3535 pairs, 15-inch Paris refractor, made in the years 1920–1933. Some new faint pairs are included.

Komendantow gives measures of 231 pairs, 15-inch Poulkova refractor (*Poulkova Circular*, No. 9).

Greenwich Astronomical Results for 1931 and 1932 contain measures of 107 and 115 pairs, made with the 28-inch.

Zagar publishes measures of 110 pairs, 14-inch Arcetri (*Atti Veneto*, **93**, part 2).

Aller (*A.N.*, **251**, 273) and Luplau Janssen (*A.N.*, **252**, 295) continue their measures.

Milburn has measures of 44 older pairs (*M.N.*, **94**, 255).

Kwasan Bull. 283 contains measures by Inaba with a 12-inch refractor.

Aitken gives measures of Sirius and two notes on Σ972 rejected (*P.A.S.P.*, **46**, 110, 109, 284).

Contrib. Astrofis. Catania has measures of 40 pairs, Astrogr. Cat. zones +48° to +54°.

Vyssotsky gives recent photographic measures of the large parallax pair BD +66°34, disclosing orbital motion (*P.A.S.P.*, **45**, 310).

Lembang Annals, VI, part 2, contains measures of 1023 pairs by Wallenquist, mostly with the 14½-inch, some with the 7-inch.

Union Observatory Circular 92 gives measures of 347 pairs by Finsen and of 486 pairs by van den Bos, almost all with the 26½-inch.

Orbits.—In the following table the reference numbers are those in Aitken's *New General Catalogue of Double Stars* (1932):—

ADS	Computer	*P*	*a*	*e*	Reference
		y	″		
61	Voronov	105·633	1·463	0·460	*Tashkent Circ.*, 27
450	,,	11·10	0·132	0·632	,, ,, 25
520	,,	24·95	0·65	0·23	,, ,, 25
671	,,	507·286	12·307	0·514	,, ,, 27
755	,,	123·016	0·936	0·712	,, ,, 27
918	,,	28·2	0·19	0·12	,, ,, 24
1598	,,	64·888	0·658	0·400	,, ,, 27
1613	,,	26·8	0·22	0·10	,, ,, 24
1630	,,	55·331	0·340	0·833	,, ,, 27
1709	,,	165·744	0·902	0·318	,, ,, 27
	Luyten	155·9	0·92	0·30	*P.A.S.P.*, **45**, 311
2028	Voronov	18·985	0·173	0·503	*Tashkent Circ.*, 27
2200	Allen	34·1	0·38	0·31	*A.J.*, **43**, 104
2616	Luyten	600	0·72	0·71	*P.A.S.P.*, **46**, 199
3064	Voronov	6·79	0·16	0·21	*Tashkent Circ.*, 24
3135	,,	90·031	0·593	0·633	,, ,, 27
3210	,,	29·364	0·278	0·213	,, ,, 27
3483	,,	92·033	0·596	0·518	,, ,, 27
3701	,,	5·32	0·110	0·04	,, ,, 27
4299	,,	20·4	0·18	0·13	,, ,, 24
5423 AB	,,	49·760	7·543	0·59055	,, ,, 30
BC, B	Volet	6·41	0·0676	0·0	*Bull. Ast.*, **8**, 55
5752	Voronov	29·8	0·24	0·45	*Tashkent Circ.*, 24
6420	,,	23·031	0·653	0·736	,, ,, 27
6650 AB	,,	57·999	0·9060	0·3341	,, ,, 19, 27
					,, *Bull.*, 2
Cc, C	,,	17·460	0·214	0·204	,, *Circ.*, 19
6871	,,	78·9	0·60	0·57	,, ,, 24
7284	,,	33·568	0·711	0·334	,, ,, 27
7334	,,	16·50	0·16	0·05	,, ,, 24
7390	,,	116·729	0·853	0·560	,, ,, 27
7545	,,	112·864	0·324	0·491	,, ,, 27
8119	,,	59·848	2·528	0·41206	,, ,, 30
8148	,,	183·3	1·92	0·65	,, *Publ.*, 4², 45
8197	,,	72·186	0·778	0·436	,, *Circ.*, 27
8239	Zagar	670	1·299	0·730	*Padova Publ.*, 36

ADS	Computer	*P*	*a*	*e*	Reference
		y	″		
8344	Voronov	85·5	0·32	0·29	*Tashkent Circ.*, 24
8630	,,	182·144	3·846	0·888	,, ,, 27
8804	,,	25·865	0·666	0·531	,, ,, 27
8974	,,	221·014	1·178	0·871	,, ,, 29
8987	,,	22·734	0·224	0·514	,, ,, 27
9031	,,	150·638	2·518	0·421	,, ,, 29
9094	,,	38·423	0·193	0·443	,, ,, 27
9247	,,	40·635	0·242	0·242	,, ,, 27
9301	,,	28·102	0·213	0·165	,, ,, 29
9343	,,	129·148	0·589	0·949	,, ,, 29
9413	,,	151·821	4·863	0·512	,, ,, 27
9494	,,	206·233	3·665	0·452	,, ,, 27
9626	,,	222·432	1·468	0·532	,, ,, 27
9716	,,	55·163	0·798	0·583	,, ,, 27
	Pitman	57·3232	0·8275	0·5780	*P.A.S.P.*, **46**, 196
	Komendantow	55·578	0·828	0·5834	*Poulkova Circ.*, 8
9757	Voronov	100·631	0·573	0·412	*Tashkent* ,, 27
9909	,,	44·645	0·726	0·753	,, ,, 27
10188	,,	120·131	0·906	0·407	,, ,, 29
10360	,,	15·689	0·158	0·135	,, ,, 29
10598	,,	46·054	1·074	0·178	,, ,, 27
10660	,,	111·304	1·589	0·227	,, ,, 29
	Rudnick	76·06	1·55	0·18	*A.J.*, **43**, 164
	Van Biesbroeck	80·6	1·51	0·10	*Ap. J.*, **80**, 270
10786	Voronov	43·244	1·321	0·204	*Tashkent Circ.*, 27
10871	,,	34·61	0·285	0·500	,, ,, 19
11046	,,	87·210	4·505	0·47208	,, ,, 30
		87·516	4·523	0·49788	
11186	Luyten	323	0·79	0·9937	*A.J.*, **43**, 105
		278	0·67	0·946	
11871	Voronov	57·132	1·243	0·201	*Tashkent Circ.*, 27
	Huffer	61·8	1·24	0·25	*Ap. J.*, **80**, 270
11950	Voronov	21·202	0·586	0·187	*Tashkent Circ.*, 27
12096	,,	2·68	0·129	0·53	,, ,, 27
12447	,,	353·124	1·132	0·930	,, ,, 29
12880	,,	319·748	2·176	0·180	,, ,, 29
12972	,,	126·984	0·638	0·186	,, ,, 27
12973	,,	25·967	0·294	0·831	,, ,, 27
13125	,,	25·731	0·278	0·543	,, ,, 27
13461	,,	85·015	0·442	0·484	,, ,, 27
14073	,,	26·702	0·468	0·348	,, ,, 29
14360	,,	134·635	0·693	0·356	,, ,, 27
14773	,,	5·698	0·265	0·401	,, ,, 27
	Luyten	5·70	0·26	0·42	*P.A.S.P.*, **46**, 199
14787	Voronov	49·234	0·934	0·241	*Tashkent Circ.*, 27
15281	,,	11·368	0·336	0·485	,, ,, 27
	Luyten	11·53	0·21	0·30	*Ap. J.*, **79**, 449
15300	Voronov	23·9	0·12	0·21	*Tashkent Circ.*, 24
15972	,,	44·427	2·483	0·365	,, ,, 27
16326	,,	95·0	0·36	0·32	,, ,, 24
16417	Van den Bos	27·0	0·151	0·98	*Union Obs. Circ.*, 92
16665	Voronov	86·110	0·802	0·785	*Tashkent Circ.*, 27
16800	,,	40·644	0·231	0·353	,, ,, 27
17052	,,	23·6	0·19	0·23	,, 24

ADS	Computer	*P*	*a*	*e*	Reference
		y	″		
17175	Luyten	26·46	0·82	0·406	*P.A.S.P.*, **46**, 199
B 1909	Voronov	9·24	0·202	0·40	*Tashkent Circ.*, 32
δ 31	,,	4·56	0·18	0·24	,, ,, 24
	Colacevich	4·60	0·175	0·27	*Rend. Acad., Lincei.*, **18**, 386
p Eri	Luyten	251	8·31	0·80	*P.A.S.P.*, **46**, 199
ψ Arg	Voronov	34·413	0·885	0·371	*Tashkent Circ.*, 27
ϕ 47	,,	5·67	0·140	0·70	,, ,, 32
γ Cen	,,	82·356	0·956	0·804	,, ,, 27
I 365	Zagar	80	0·369	0·032	*Padova Publ.*, 36
Mlb O 4	Voronov	41·018	1·803	0·546	*Tashkent Circ.*, 27

Luyten, using Washington meridian observations, derives an absolute orbit for the spectroscopic binary γ Gem, period 5·96 years (*A.J.*, **43**, 109).

The motion of ADS 1123 is discussed by van den Bos (*U.O.C.*, 92).

Finsen gives a catalogue of visual binary orbits in *U.O.C.*, 91.

Miscellaneous.—Barbier has published, as a dissertation, a statistical study of long-period binaries (*Bull. Astr.*, **8**, 131, 169).

Seyfert has studied the influence of discovery-selection on the distribution of the eccentricities of visual binary stars (*Harvard Bull.*, 896).

Kuiper investigated the frequency of the physical pairs having separations between 1/20 and 5 parsecs (*B.A.N.*, **7**, 227).

Plaut gives a list of double stars with variable components (*B.A.N.*, **7**, 181).

Kovalenko (*A.J.*, **43**, 195) derives the masses of 85 Peg from parallax plates, finding the brighter star three times more massive than the fainter. Earlier determinations had assigned the greater mass to the fainter component. Equally controversial are the various determinations of the magnitude of Sirius B. Huffer and Whitford (*P.A.S.P.*, **46**, 221), from photo-electric observations with the 100-inch telescope, find 7·3 in close agreement with Vyssotsky's photovisual result; Kuiper (*P.A.S.P.*, **46**, 99) finds 8·5 by visual methods and criticises Vyssotsky's derivation.

Huffer has determined the mass ratios of a number of visual binaries from photographic plates taken with the 40-inch refractor (*Ap. J.*, **80**, 269).

W. H. v. d. B.

Nebulæ

The present general survey of Nebulæ covers the last three years. During this time a great deal of material has accumulated, dealing with both Galactic and Extragalactic Nebulæ. It has been suggested that some different terms might be adopted to denote the two classes. The distinction between them is indeed so great that although the word "nebula" is thoroughly justified as a description of the galactic objects some other appellation should be used for the extragalactic systems, which are now established to be comparable to the Galaxy itself in dimensions and constitution. The terms "Galactic" and "Extragalactic" were, however, adopted by the Commission on Nebulæ of the I.A.U. in 1922, and it lies with this Commission to make a change if it is thought desirable.

Extragalactic Nebulæ

Distances and the Spectrum Line Displacements

A Council note on "The Distances and Spectrum Line Displacements of the Extragalactic Nebulæ" appeared in *M.N.*, **92**, 347, 1932. This dealt with the observational evidences for the expansion of the universe, based principally on the work of Hubble and Humason up to that date. The same authors have contributed a paper on "The Velocity-Distance Relation for Isolated Extragalactic Nebulæ" to the *Proceedings of the National Academy of Sciences*, **20**, No. 5, 1934. The earlier work included 50 of these isolated systems (as distinct from objects occurring in distant groups) and Humason has now added 35 to the data available. The nearer systems (the Magellanic Clouds, M31, M33 and N.G.C. 6822), which give velocities attributable to the effects of the rotation of the Galaxy, have been eliminated from the discussion, as well as two which give apparently anomalous results, viz. I.C. 342, $v = -25$ and N.G.C. 404, $v = +40$ (corrected for galactic rotation).

The frequency distribution of absolute magnitudes among systems of a given apparent magnitude is found to be a normal error-curve, but with the maximum displaced towards the brighter side by the systematic term $1{\cdot}38\sigma$. The relation between the integrated magnitude m and the velocity is given as

Isolated Neb.	$\log v = 0{\cdot}2m + 0{\cdot}71$,
Cluster Neb.	$\log v = 0{\cdot}2m + 0{\cdot}51$.

The anomaly is explained as being the result of selection.

It was pointed out by Knox-Shaw in his Presidential Address in 1933 February (*M.N.*, **93**, 311) that the isolated nebulæ gave a considerably larger rate of expansion than the cluster objects, the two amounts being 584 and 419 km./sec. respectively.

In this address, Knox-Shaw adopted the scale of photographic magnitudes given in *Harvard Annals*, **88**, 2, 1932, by Shapley and Miss Ames, in preference to the admittedly rough visual estimates of Holetschek, originally used by Hubble in obtaining his first estimate of the distance-velocity relation. This enabled him to reduce the range in magnitude of the intermediate and late types, and he found the value of $m_s - m_n$ (the difference between the apparent magnitudes of the brighest stars and the integrated magnitudes of the nebulæ) to be 8·4, in place of Hubble's value 8·9. This led to a revision of the mean absolute photographic magnitude from $-13{\cdot}8$ to $-14{\cdot}5$, which represents an increase of 38 per cent. in Hubble's scale of distances.

It is evident that the quantitative determination of the velocity-distance relation is still subject to considerable uncertainty, and depends to a large extent on the adopted scale of absolute integrated magnitudes of the nebular systems.

Comparative Dimensions of the Galaxy and the Extragalactic Nebulæ

The apparent large discrepancy between the linear dimensions of the Galaxy and the spiral nebulæ has been the subject of considerable discussion recently. On the one hand, doubts have been expressed as to the validity of the earlier results of Shapley, who gave 100,000 parsecs as the probable diameter of the Galaxy. It has been suggested that even a slight absorption of light in the plane of the Galaxy by diffuse matter, such as undoubtedly exists in the dark galactic clouds, would have the effect of reducing the real magnitudes of stars and globular clusters, thus leading to estimates which are considerably greater than the actual dimensions.

Trumpler has adopted a value of $0^m.67$ (photographic) per kiloparsec for the absorption coefficient in the plane of the Galaxy, and the existence of such a layer would diminish the light in all galactic latitudes to a degree proportional to the co-secant of the latitude. In a further test of this hypothesis Van de Kamp in *A.J.*, **42**, 97, 1932, has also made use of *Harvard Annals*, **88**, 2, 1932. He derives from the number of nebulæ down to the same magnitude over the whole sky, a value of 0·8 for the optical depth of the absorbing layer, the position of the Sun being about four-tenths of the way from the northern to the southern edge. Knox-Shaw, however (*loc. cit.*), found that the adoption of this value gave anomalous results, and if there is such an absorbing layer its optical depth must be a much smaller value than 0·8. The question of the real dimensions of the Galaxy has to be regarded as still very uncertain within a wide range, but there seems to be a consensus of opinion that it cannot be reduced to less than 30,000 parsecs.

On the other hand, evidence has been forthcoming that the dimensions of the spiral nebulæ are greater than has been hitherto supposed. The use of recording microphotometers of high degree of sensitiveness has extended the photographic ranges beyond the limit of visual estimates by at least 20 per cent., and in a great many cases by a much larger percentage.

Shapley treated this subject with considerable detail in his George Darwin lecture, delivered 1934 May 11 before the R.A.S. (*M.N.*, **94**, 791, 1934). He finds that the angular diameter of the Large Magellanic Cloud hitherto taken as $7^\circ.2$, is now shown by star counts, by microphotometer tracings on small-scale long-exposure plates, and especially by newly found outlying globular and open clusters to be at least 12°, corresponding to a linear diameter of 5·5 kiloparsecs. Similarly the diameter of the Small Cloud is increased from $3^\circ.6$ to $8^\circ.0$.

But the most striking and important result has been obtained for the Andromeda Nebula. The dimensions of the photographic image by visual estimates have given values ranging from 130′ to 160′. It is, in fact, a difficult matter to estimate by eye the point where the darkening of the film due to the nebula merges into the background density of the plate.

By means of densitometer tracings on small-scale plates of long exposure, taken with lenses from 1·5 in. to 4 in. diameter and focal ratios from 4 to 7, a

length of 4°·5 and a width of 4° was found. The tracings thus indicate that although the length is four times the width for the projection of the brighter parts of the nebula, the system is almost spherical in terms of light which lies near the limit of registration. In this connection may be mentioned Hubble's paper "Nebulous Objects in M31 provisionally identified as Globular Clusters," *Mt. Wilson Cont.*, 452, 1932. One hundred and forty nebulous objects, appearing as small condensed globular nebulæ from 4″ to 10″ in diameter, with the magnitudes ranging from about 15 to 18, were found in the regions around the system. The number of these objects per unit area decreased with the distance from the nuclear point of M31, and occasionally were encountered as far as 3°·5 from the nucleus. From their forms, colours, luminosities and dimensions they have been provisionally identified by Hubble as globular clusters. They are, however, systematically fainter than the globular clusters of the Galaxy by at least 0·75 mag., and possibly as much as 1·95 mag. Shapley thinks that many of them should be classed as open rather than globular clusters.

Shapley has also obtained densitometer tracings of 66 nebulæ in addition to M31, all of which show considerable increases on the angular diameters derived from reflector plates. In particular the spheroidal or elliptical nebulæ show a much larger increase than the spirals, the factors being 5·5 and 2·3 times respectively. On the other hand, the condensed later-type spirals such as N.G.C. 253, 3031 and 4517 are only increased by 50 per cent. in diameter. The reflector values, therefore, are necessarily to be taken as the diameters up to a limiting luminosity only, but they are important as defining this.

The same order of results, but by the direct application of a photoelectric photometer at the Newtonian focus of the 100-inch reflector at Mt. Wilson, was obtained by Stebbins and Whitford (*Com. Nat. Ac. Sc.*, No. 113). They confirm Seares's conclusion that the central region of M31 is at least 5 magnitudes or 100 times brighter than the part of the Galaxy in the neighbourhood of the Sun.

Distribution of the Extragalactic Nebulæ

The distribution of extragalactic nebulæ to a limiting photographic magnitude of 20 is the subject of an important paper by Hubble in *Mt. Wilson Cont.*, 485, 1934. The material consists of about 44,000 nebulæ distributed over three-quarters of the sky north of −30° Dec. By far the greater proportion are very faint and distant nebulæ, which seem to give results at variance with the brighter and close systems taken by themselves which have been eliminated in the discussion. Thus Hubble finds that systematic variations in longitude are appreciable only in lower latitudes, where obscuration appears to be conspicuously greater in the direction of the galactic centre than in the opposite direction. There is a definite variation in latitude which from the poles to 15° in both hemispheres is represented by the formula

$$\log N_m = C - 0{\cdot}15 \operatorname{cosec} \beta.$$

With allowance for the effect of the red shift with distance the rate of increase of log N with exposure time suggests uniform distribution in depth. An interesting account is given in the paper of the "belt of avoidance," so far as it is evident from an examination of the available data, which extends from longitude 300° through 0° to 210°. There is, therefore, 90° of longitude omitted, all of it in the southern hemisphere of the sky. The zone consists of a narrow belt 10° to 20° wide, centred on the galactic plane, from which several great protuberances extend into the higher latitudes. The two which extend farthest coincide with the ends of the inclined belt of helium stars and diffuse nebulosity where it reaches its greatest distance from the plane. There are in addition two detached areas, one centred about $\lambda = 335°$, $\beta = +35°$, the other near $\lambda = 145°$, $\beta = -35°$.

A similar investigation was undertaken at the Lick Observatory by N. U. Mayall (*L.O.B.*, No. 458, 1934). His data were obtained from 489 Crossley reflector plates, on which about 15,000 small nebulæ were counted, up to 19^{m}(ph). Compared with Hubble's results there were no outstanding discrepancies, and there is general agreement between these two independent pieces of work. At the same time, the areas photographed are selected areas and the southern hemisphere is only partially represented.

Hubble's paper was limited to the background of faint and small nebulæ usually under a minute of arc in diameter. In *H.C.O. Bulletin*, No. 887, Shapley and Ames give a preliminary notice of the "Photometric Survey of the Nearer Extragalactic Nebulæ," which has since been published by them in the *Annals*, **88**, 2, 1932, already referred to. It consists of more than 1000 extragalactic objects brighter than the 13th mag., and covers the whole sky on a uniform system.

The distribution of these is found to lack homogeneity, thus confirming results based on a more restricted range by Reynolds in *M.N.*, **83**, 147, 1923, in which paper spiral nebulæ are plotted in three classes according to their angular diameters. There are certain regions which are barren of nebulæ brighter than the 13^{th} integrated magnitude, and as these regions contain fainter objects in normal profusion, the deficiency cannot be the result of obscuration. The general distribution of these brighter and presumably nearer nebulæ, both spiral and spheroidal, is represented by a broad band 40° in diameter along an axis λ 100° – 280° in the north galactic hemisphere. There are large almost vacant regions on each side of this band. In the south galactic hemisphere two principal bands of concentration are apparent, leaving the south galactic polar region with very few examples. It may be pointed out, however, that the spirals which do lie in this latter region are of very large angular diameter. In both galactic hemispheres the quadrants 0° to 90° contain relatively few compared with the other quadrants.

A still further restricted range of spiral nebulæ is considered in a paper by Reynolds on "The Spatial Distribution of the Extragalactic Nebulæ within a Radius of 4000 Kiloparsecs" (*M.N.*, **94**, 196, 1934). The criterion of distance is in this case taken as the angular diameters, all of which exceed 5′. This criterion is, in the writer's opinion, better than that of the integrated magnitudes where only a limited number of nebulæ of large angular

diameter are considered. In the case of the spirals whose planes are considerably inclined to the line of sight, such as the edge-on spirals, the integrated magnitudes must necessarily give very misleading results as to their absolute luminosity. As the mean of the random angles of inclination is 30°, and a large proportion of the nearer spirals are inclined at less than this, the point is of considerable importance. Tables are given of probable distances, angular diameters (derived from reflector plates), and approximate diameters in parsecs. The angular diameters are subject to the photometric modifications already mentioned, and should be increased, except in the case of edge-on spirals, by at least 30 per cent.

In general it is found that there is a preponderance of extragalactic systems in the south galactic hemisphere up to a distance of 700 kiloparsecs. Beyond this range the preponderance passes to the north galactic hemisphere up to 4000 kiloparsecs, which is the limiting radius dealt with.

H.C.O. Bull., 895, 1934, contains a paper by Bart. I. Bok on "The Apparent Clustering of External Galaxies." In this Hubble's results on the background of faint spiral and elliptical nebulæ are analysed on a theoretical basis. Bok calculates the form of the frequency function for the number of galaxies per unit area of the sky, on the assumption that they are distributed at random. He compares first the Shapley-Ames Catalogue of Galaxies brighter than the 13th mag. with the computed values and finds that, as might be expected from the known distribution, there is a large discrepancy between the two. Hubble found from his more extended material that "the frequency curve of the log N_m closely approximates a Gaussian error curve." Bok points out that a comparison of Hubble's observed frequency curve with the curve of calculated random distribution after an ample allowance for dispersion in limiting magnitudes has been applied, brings out very clearly that the distribution of these faint extragalactic nebulæ is also not at random. He therefore concludes with Shapley and many others that the general distribution is not homogeneous, and the tendency towards clustering is one of the chief characteristics of the extragalactic universe, as far as we can plumb its depths. This conclusion is an important one from the theoretical and cosmological point of view where an approximate equable distribution of matter is assumed.

Galactic Nebulæ

Dark Nebulosities

The general relationship which exists between the dark clouds of gas and matter in interstellar space and the diffuse nebulæ is now generally recognised. The Orion nebulosities are local areas on the near side of such a cloud, dependent on B-type stars for their radiation by ultra-violet absorption, and re-emission in the characteristic radiations. The regions of the "American Nebula" in Cygnus have been made the subject of photographic study in America, especially with the 100-inch reflector at Mt. Wilson, and during the last two years the new reflector of 80-cm.

aperture installed at Forcalquier (Basses Alpes) has produced in the hands of de Kerolyr some beautiful photographs of the diffuse nebulæ in this region. These show very clearly that the nebulosities lie along the margin of an extensive dark cloud in which the star counts are only about a tenth of the counts on the other side of the nebulosities. Other photographs obtained by de Kerolyr include the "Pelican" nebula I.C. 5070, a filamentous nebula, N.G.C. 6992, and I.C. 5146, all of them in Cygnus. Mention should also be made of a photograph of the nebulæ in the Pleiades, which shows hitherto unrecorded intricacies of structure around the brighter stars.

A paper by de Kerolyr on N.G.C. 6992 appears in *L'Astronomie* for 1934 January. He points out that the spectrum of this nebula was found by Hubble to be pure emission, and asks what stars are responsible for the luminosity of the filaments of nebulosity, as apparently no star anterior to B3 appears to be associated with it. He suggests that some star or stars obscured more or less by dark nebulosity might be the hidden source of radiation.

Meddelanden från Astronomiska Observatorium Upsala, No. 55, 1931, contains an extensive investigation by Carl Schalén on "The Distribution of Stars in Galactic Regions in Relation to the Dark Nebulæ." The regions investigated were in Cygnus, Cepheus, Cassiopeia and Auriga, and the stars in relation to them were of types G, K and M, the B and A types having already been considered in a previous paper. In the first two chapters Schalén deals first with the stellar material employed, the spectral types and the photographic magnitudes, then with the mean absolute magnitudes and the spatial distribution of the stars. The third chapter gives an account of five different methods of determining the distance and absorption of a dark nebula. These are based on star counts brighter than successive photographic magnitudes, assuming that the dispersion in absolute magnitude is small. This method was due to Wolf. A modification of this is adopted by Schalén. By comparing the star density curves in the apparently unobscured and the obscured regions the curves of the one can be derived from the other, if an appropriate assumption for the absorption factor in depth be made. From this the distance of the nearer edge of the cloud can be deduced. Of course in order to calculate the depth of the cloud a further assumption has to be made that the density of the clouds is constant. This seems to be the weakest part of the investigation, for the visible edges of dark nebulæ show great variations in absorption, and it is very probable that the clouds vary considerably in degree of opacity, from one to another. In the case of the Cygnus cloud, centred at $20^h\ 25^m$, $+35°$, a distance is derived of 600 parsecs for the nearer boundary, with a radial extension of 300 parsecs, the total absorption being 2 mag. The nearest is the cloud in Auriga, centred at $4^h\ 45^m$, $+36°$, the distance of the nearer boundary being 70 parsecs, the radial extension 380 parsecs and the total absorption 1·9 mag. In No. 58 of the same publication, a quantitative estimate is given of the colour-excess of stars involved in the obscuring clouds of these regions. The spectra were obtained with an objective prism camera of small dis-

persion, and the colour equivalents were determined by intensity measures of two narrow strips at λλ 3950 and 4400 in the spectra of A- and B-type stars, both in the obscured and open regions. The result was found to be a conspicuous reddening of the stars involved in the clouds :

Region	Total Photographic Absorption	Selective Absorption
	m	m m
Cygnus	1·5	0·15 – 0·20
Cepheus	0·9	0·07
Auriga	1·9	0·21

On these data a discussion as to the physical constitution of the dark clouds is based, the assumption being that the matter consists of minute metallic particles. But it is unlikely that the clouds consist only of such particles, as we know that free hydrogen, helium and oxygen are present in the Orion and other clouds from the emission spectra of visible diffuse nebulosities. An inspection of photographs, such as that of the dark nebulosity near ζ Orionis, seems to indicate that complete opacity at a comparatively shallow depth is a common feature in these areas of the sky.

A previous investigation, "On the Apparent Magnitudes of the Foreground Stars of Dark Nebulæ," by W. Gyllenberg, also appears in the *Meddelanden från Lund's Astronomiska Observatorium*, Ser. II, No. 52. In this paper the magnitudes and numbers of the foreground stars alone are considered. Schalén's work includes the spectral types in addition, which is an important element in the problem. "The Distance of the Cygnus Cloud" is a later work by W. Baade (*Mt. Wilson Cont.*, No. 493, 1934). Values of the distance of the cloud are derived from three groups of stars—eclipsing systems, long-period variables, and early B-type stars—the centre of the region in this case being $19^h\ 52^m$, $+38°\ 13'$. He finds the mean of the resulting distance modulus $m - M = 12·7$. Taking into account the effects of selective absorption, the upper limit of the real distance comes out as $D < 2630$ parsecs, a much larger estimate than that of Schalén for the neighbouring region.

Planetary Nebulæ.

A great deal of work has been done on planetary nebulæ during the last three years, principally in theoretical discussions based on their forms and spectra. Zanstra and Ambarzumian have contributed several papers on radiative equilibrium, both in a stationary and expanding nebula. They are founded on Zanstra's theory of nebular luminosity, according to which all quanta emitted from the central star having frequencies greater than the limit of the Lyman series are absorbed by the hydrogen atoms in the nebula. The nebulous shell re-emits these quanta as L_α-quanta, L_α being the first line of the Lyman series of hydrogen. Owing to the large optical thickness of the nebula in the L_α-line, and to the fact that all L_α-quanta absorbed are re-emitted in the same frequency, the density of the radiation in the inner layers of the ring is very large. Radiation-pressure due to this

radiation is thus preponderant and very much greater than the force of gravity of the central star (Ambarzumian, *M.N.*, **93**, 50, 1932, and *Bull. de l'Obs. Astr. à Pulkovo*, **13**, 3, 1933).

The natural explanation of the central doubling and curving of the ends of the N lines in certain planetaries found by Campbell and Moore under a high dispersion (*L.O. Pub.*, **13**, 77, 1918) is that there is an actual expansion and rotation of the gaseous shell in such cases. In "The Expansion Hypothesis for Planetary Nebulæ" (*M.N.*, **93**, 131, 1932) Zanstra deals with the alternatives—equilibrium without rotation, and equilibrium with rotation and expansion. He concludes that equilibrium without rotation is an impossibility owing to the absurdly high concentration of matter required in the central star. If a planetary nebula does not rotate it cannot be in equilibrium and must either expand or contract. On gravitational grounds Zanstra concludes that expansion and not contraction is the only possible explanation, especially if we take into account the considerable amount of evidence which exists for the origin of planetaries from novæ.

In order to accord with observation it is necessary to assume that not one velocity but a range of velocities occur in the ejected envelopes. The possible influence of radiation-pressure and of gas-pressure is discussed, but no account is taken of the material which after ejection returns to the star in course of time.

A further paper on "Radiation-pressure in an Expanding Nebula," by Zanstra, appears in *M.N.*, **95**, 83, 1934.

In an expanding nebula the radiation-pressure due to L_a is calculated to produce a velocity of 200 km./sec. in the envelope of a planetary nebula of radius 10,000 astronomical units. This is contrary to observational evidence which requires an average velocity of only 10 km./sec. By an extension of Ambarzumian's methods Zanstra finds that for an expanding nebula, where the mechanical velocity v is proportional to the optical depth, the radiation-pressure is only $1/3\left(\frac{W}{v_L}\right)^2$ of what it would be for a stationary nebula with the same thermal width W, if V_L is the velocity range of the main luminous portion of the envelope. Hence a reduction of radiation-pressure as required by observation may be obtained, if the thermal width W is much smaller than the luminous width V_L.

In *Mt. Wilson Cont.*, 463, 1933, van Maanen deals with the proper motions of 21 planetary nebulæ, from which he has derived a mean parallax of $0''{\cdot}0007$. *L.O.B.*, No. 462, 1934, also contains a study of the proper motions of 33 planetary nebulæ, by C. M. Anderson, who finds the same value for the mean parallax, the average and relative proper motion in a great circle being $0''{\cdot}0117$. The mean absolute photographic magnitude of the central stars is given as 0·9, the mean linear diameter of the planetaries being 0·55 parsecs.

Two other papers by Ambarzumian appear in *Pulk. Obs. Circ.*, Nos. 4 and 6, the one on the temperatures of the nuclear stars, the other on the metastable states in the gaseous nebulæ. J. H. R.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE CONTRIBUTED TO THE LIBRARY, ETC., DURING THE YEAR 1934

(*Institutions exchanging publications with the R.A.S. Library are omitted from the list, in order to economise in printing*)

Allahabad, Academy of Sciences
American Association of Variable Star Observers
Astronomical Society of South Africa
Barcelona, Observatorio Fabra
Belgrade, Observatoire Astronomique de l'Université
Bern, Schweizerische Geodätische Kommission
Bordeaux, Société Astronomique
Bordeaux, Société des Sciences Physiques et Naturelles
British Association for the Advancement of Science, Tables Committee
British Horological Institute
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Canada, Royal Canadian Institute
Canada, Royal Society
Canton, Observatoire de l'Université Sun Yat Sen
Carnegie Institution of Washington
Cracow, Académie Polonaise des Sciences et des Lettres
Société Astronomique Flammarion de Genève
Genoa, Istituto Idrografico della Regia Marina
Gorki (Nishni-Novgorod), Verein von Freunden der Physik und Astronomie
Helsingfors, Finnisches Geodätisches Institut
Hyderabad, Nizamiah Observatory
International Astronomical Union
Johannesburg, University of the Witwatersrand
Kiew, Observatoire
Kyoto Imperial University, Kwasan Observatory
London, Institute of Physics
London, Science Museum
Lourenço Marques, Observatorio Campos Rodrigues
Mauritius, Royal Alfred Observatory
Merate, Reale Osservatorio Astronomico
Mizusawa, International Latitude Observatory
Montpellier, Académie des Sciences et Lettres
Moscow, Astronomical-Geodetical Society of USSR
Moscow, State Research Institute of Geodesy and Cartography
Nantucket, Maria Mitchell Association

Netherlands Indies Science Council
Oporto, Faculdade de Sciências
Oxford, Radcliffe Observatory
Peiping, National Tsing Hua University
Pulkovo, Astronomical Observatory
Rome, Reale Accademia d'Italia
Talence, Observatoire
Tashkent, Astronomical Observatory
Tashkent, Unversitas Asiæ Mediæ
Tohoku Imperial University, Astronomical Institute
Tokyo, National Research Council of Japan
Tokyo, Physico-Mathematical Society of Japan
Vassar College Observatory
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ADDRESS

Delivered by the President, Professor F. J. M. Stratton, on the award of the Gold Medal to Professor Edward Arthur Milne.

The Council of the Society have awarded the Gold Medal to Professor Edward Arthur Milne for his work on Radiative Equilibrium and Theory of Stellar Atmospheres, and it is my happy privilege to lay before the Fellows the grounds of the Council's award.

Milne's first contribution to the subject of radiative equilibrium was published in our *Monthly Notices* for 1921 March, shortly after a vacancy at the Solar Physics Observatory had given Professor Newall the opportunity of inviting Milne into the ranks of professional astronomy, an invitation which most happily for our science was accepted. As is the case with most of the papers to which I shall have to refer to-day, the opening paper is largely mathematical: I am not, however, going to occupy your time to-day with an account of the mathematical difficulties which Milne encountered in his work nor of the integral equations which have played so important a part in stellar physics; rather I want to turn your attention to the important physical results derived from Milne's theoretical discussions of the problems dealt with by Schuster in his paper on "Radiation in a Foggy Atmosphere" (*Ap. J.*, **21**, 1, 1905), and by Schwarzschild in his work on Radiative Equilibrium (*Göttingen Nach.*, 1906).

In examining the radiative equilibrium of a star's outer atmosphere he takes the thin outer layers studied to be in a steady state: he assumes the energy radiated from each thin stratum to be the same as that generated externally and entering the stratum; he derives a correction for Schwarzschild's formula connecting temperature, T, with optical depth, τ,—a formula which left implicit a warming of the outer layers of the star's atmosphere. Milne's formula, which has replaced that of Schwarzschild, is $T^4 = T_0^4(1 + \frac{3}{2}\tau)$, where T_0 is the temperature at the outermost boundary where the entrant radiation is zero. He deduces an approximate value, 1·232, for the ratio T_1/T_0, where T_1 is the effective temperature deduced with the aid of Stefan's constant from the total radiation from the whole disc. Schwarzschild had obtained a value of 1·189, and Jeans of 1·278 for this same ratio. Closely connected with the ratio T_1/T_0 is the law of darkening at the limb. If q is the ratio of the intensity of radiation escaping in a direction θ to that escaping normally ($\theta = 0$), Milne writes $q = 1 - u(1 - \cos\theta)$ and calls u the coefficient of darkening. He derives for this coefficient the value 3/5, whereas the Schwarzschild-Jeans value had been 2/3.

He next examines the effect of his treatment of the flux of radiation through the star's outer layers on the spectral distribution of the emergent radiation and finds that it is approximately that of a Planck curve displaced slightly towards the violet. The theoretical discrepancy between the solar

temperature derived from the wave-length of maximum intensity and that derived from the solar constant—the former being 3·1 *per cent.* higher than the latter—is in the same direction as that found by observation by Abbot, though only half of the observed amount. The wave-length of maximum energy is displaced in Milne's theory to the violet by different amounts at different points of the disc, the displacement decreasing from a maximum at the centre to a zero value at the limb. Here theory and observation are not in accord.

Milne now extends his theory to the law of darkening of a stellar disc towards the limb, and its relation to the distribution of energy in the star's continuous spectrum.* He finds that for grey matter, for which the coefficient of absorption is independent of wave-length, the darkening at the limb compared with the centre decreases as λT_0 increases. If we have radiative equilibrium, grey matter, no selective absorption and no scattering, then for any given wave-length blue stars should show less darkening at the limb than red stars, though the total darkening in integrated radiation would be the same—the apparent paradox being explained by the different distribution of radiation in the two stars. No observational tests of this point from the stars are available, but, under the conditions given, theory does enable us to determine the range, 3/5 to 1/2, in which the coefficient of darkening must lie. A further point arising from the theory is that where the curve of the observed continuous spectrum of a star lies above that of a corresponding black body curve of equal area the darkening should be greater than normal, and *vice versa.*

These points cannot be examined in the stars, so Milne again turns to the Sun to see how far it supports his theories. In full detail he examines the different effects of scattering and absorption, attempting to discriminate between the two disturbing factors. He comes to the conclusion that though the observed darkening of the Sun's disc towards the limb is in strikingly good accord with the theoretical darkening of a black body in radiative equilibrium, yet the distortion of the observed energy curve cannot be explained as due either to absorption or to scattering, or even to a blend of the two. Scattering can be ruled out, at any rate for an optically thick layer and probably altogether. The theory fails to explain the deviation of the Sun's energy curve from that of a black body, while the darkening follows closely the law for a black body. Moreover, as the temperature found from Planck's law (or the energy curve) is higher than that found from Stefan's law (or the solar constant), we have the further fact that the darkening found is too low in amount, agreeing with that for an energy curve of a higher temperature.

The explanation of these discrepancies was to come later in the work of Lindblad and H. H. Plaskett. They showed that Abbot's use of a broad slit had distorted the absolute value of the intensity of the continuous spectrum, while leaving untouched its variation across the disc; Plaskett further pointed out that the distribution of the continuous spectrum between the absorption lines was that of a grey body. Lindblad also

* *Phil. Trans.*, A 223, 201, 1922.

pointed out that if the energy removed in the absorption lines was returned to the lower layers they would have their temperatures raised and the rate of decrease of intensity from centre to limb would be reduced. When at a later date Minnaert published his estimate that c·15 of the emergent radiation was dammed up in the Fraunhofer lines and returned inwards, Milne showed * that this figure agreed well with the value required by Lindblad and himself to fit theory and observation. The general conclusion is a very good agreement of the two—theory and observation—with a reminder that the term solar temperature is uncertain, depending on the level to which it is applied. Layers of differing temperature shade off into each other, and with lines of different intensities we penetrate to different depths.

Before turning to the second ground of the award of the medal I must refer briefly to two short papers dealing with quiescent outer layers, or let us say the stratosphere of a star † and of a planetary nebula.‡ In the first of these Milne shows that the temperature of the outer layers—above the limb—cannot fall off more rapidly than as the inverse square root of the distance from the centre (the case of grey material), and may fall off much more gradually, especially if they absorb selectively in the far ultra-violet. In the second paper he examines the determination of the true brightness of the central star of a planetary nebula, regarded as surrounded by a spherical shell of grey matter. He disarms the criticism that the outer shell of a planetary nebula is not grey matter, if we interpret spectroscopic results aright, by suggesting that his problem is an easier one to tackle as a preliminary to the actual problem. As so often in Milne's work, useful by-products of a mathematical nature spring incidentally from the investigation. In the earlier work referred to above he has developed most of the mathematical methods which have since been much used in the discussion of the formation of absorption lines. So here he shows how by an appropriate choice of boundary conditions he can extend to a spherical shell his approximate study of a plane stratum in radiative equilibrium.

I pass now to a fresh subject of our medallist's studies—the intensities and widths of absorption lines in stellar spectra. He approached this in a couple of papers § in which, with R. H. Fowler, he examined Saha's theory of high temperature ionisation. For the application of statistical mathematical methods these authors made a great step forward when they replaced Saha's marginal appearance of the lines of an element by the stage of maximum strength. Assuming that the intensity of an absorption line is proportional to the concentration in the stellar atmosphere of atoms capable of absorbing the line, they connected the mean pressure and the temperature of the atmosphere with the maximum strengths of the lines ; at first they limited themselves to lines of subordinate series of neutral atoms and to principal and subordinate series of singly ionised atoms, but later they

* *Observatory*, **51**, 89, 1928.
† *M.N.*, **82**, 369, 1922.
‡ *Zeit. f. Ast.*, **1**, 98, 1930.
§ *M.N.*, **83**, 403, 1923 ; **84**, 499, 1924.

extended their results to higher degrees of ionisation. Observation of stellar material gave the approximate temperatures, and it was found that consistent results from various elements for the same star could be obtained if the pressures of the levels in which the absorption lines were formed were of the order of 10^{-4} atmospheres; this was a considerably lower value than had previously been assumed, but it has since been generally adopted. With this value of the pressure of the reversing layer a stellar temperature scale was drawn up for the different spectral types, which gave higher temperatures for the earlier type stars than had been obtained from previous work on colour temperatures. The trend of recent investigations has been towards the high figures found by Fowler and Milne.

In three later papers* Milne has extended and modified the earlier work on Saha's theory. Other workers—notably Unsöld, Adams and Russell, Miss Payne and Hogg—had meanwhile come into the field, and Milne's earlier ideas of a *concentration* of atoms and a *mean pressure* are now replaced by the *total number* of atoms above a given level and the *electron pressure* at that level. The whole idea of maximum absorption is clarified by a new definition in which the total intensity of a line is replaced by its width to a given optical depth: a line is for Milne's modified theory at maximum strength when the distance is greatest from the centre of the line to a point where its intensity has a given arbitrary ratio to that of the neighbouring continuous. Line profiles now begin to play an important part in the theory, and these call for an ever-increasing accuracy and exactitude on the observational side.

New results of great physical interest can be obtained from the generalised theory. Thus the values of electron pressures at given optical depths can be studied, and either the value of surface gravity, g, or that of the absorption coefficient, κ, can be obtained. Uncertainty still lies mainly in the question whether the absorption coefficient is constant or varies with the electron pressure; the latter hypothesis receives most support from the increased strength of the lines due to both neutral and ionised atoms as we pass from dwarfs to giants of the same temperature. Milne's generalised theory accounts satisfactorily for the increase of strength of the Balmer lines in giants as apart from dwarfs, and gives an explanation of the empirical method of stellar parallaxes. There remains work yet to be done in securing and analysing large masses of spectroscopic material to give a proper theoretical foundation for the method of spectroscopic parallaxes, and in seeing how completely theory and observation can agree. From any lack of final agreement that may be found in the future, we can always hope that some new and important development may spring.

I must pass next to yet another fundamental contribution made by Milne to the study of stellar atmosphere—namely, his theory of the equilibrium of the calcium chromosphere.† The fundamental idea of his theory is that at high levels above the Sun's surface the atmosphere may be regarded as consisting effectively of ionised atoms of calcium capable of transitions

* *M.N.*, 89, 3, 17, 157, 1928.
† See *M.N.*, 84–86 *passim*.

between two stationary states. Atoms in the lower state absorb quanta of the necessary frequency to raise them to the higher state from radiation, mainly from below, with an accompanying upward pressure. These atoms re-emit the radiation of the same frequency equally in all directions. The net result is a support against gravity due to the radiation from below—arising from the residual intensity at the centre of the corresponding solar absorption line. A statistical equilibrium is thus set up for the calcium chromosphere.

The theory can be tested in various ways. Thus it gives rise to a value of the average life of the excited calcium atom which is consistent with values suggested by laboratory observations. It suggests a law of relative strengths at different heights in the chromosphere of the ionised calcium lines H and K, compared with the triplet in the infra-red at 8498, 8542, 8662 A. Attempts have been made to test this point for the last eight years at solar eclipses, but fate has been unkind, and the crucial experiment still remains untried. Eclipse results from an examination of the rate of decrease of intensity at high levels of the bright calcium lines should also give information as to the proportion of the total support of the high calcium chromosphere, which is to be attributed to radiation pressure. Here again eclipse observers must wait for kinder weather than has fallen to the lot of the various British expeditions for some years past.

The work of S. A. Mitchell and Miss Williams on eclipse chromospheric spectra has indeed shown that for singly ionised calcium and magnesium selective radiation pressure is much more important in determining the density distribution with height than for neutral iron or singly ionised titanium, and may indeed be the chief factor. But most of their work and also Menzel's study of the flash spectra, secured by the moving-plate camera used in eclipse expeditions from the Lick Observatory, refer mainly to lower levels where many of Milne's simplifying assumptions do not hold, and hence they cannot be regarded as effective tests of his theory.

Other tests may be, however, regarded as coming from a development of the theory which Milne himself has made. In a paper published before the emergence of the idea of a calcium chromosphere balanced between gravity and radiation pressure, Milne had examined the question of the escape of molecules from the outer layers of a star's atmosphere * in equilibrium under gravitation. It was natural to extend the idea to atoms in equilibrium under the combined forces of radiation pressure and gravitation. Here Milne found that, for varying radiation from below, the equilibrium was unstable.† If an atom of ionised calcium is in a condition where the two forces balance, it will absorb radiation from light whose wave-length is equal to that of the centre of the broad calcium line K. Now let an extra outburst of radiation come from the irregularly cloudy solar atmosphere below. The atom will be accelerated upward. Its upward velocity from the Sun will involve its absorbing light of a slightly shorter wave-length coming from below. For such wave-length (differing from that of the centre

* *Trans. Cambridge Phil. Soc.*, **23**, 483, 1923.

† *M.N.*, **86**, 459, 1926.

of the absorption line) the intensity of the light from below will be stronger ; the atom will continue to be accelerated upwards more and more, until it is either driven away from the Sun entirely or becomes doubly ionised and no longer subject to the same absorption and upward pressure. If, on the other hand, the region below the balanced atom becomes temporarily cooler and the atom descends under gravity, then the upward pressure will increase as the atom comes out of the shelter of the centre of the absorption line ; the atom will be driven upwards again. There is therefore instability for upward motion and stability for downward motion. The net result is that atoms may generate a high upward speed, and be finally shot away from the Sun ; Milne has calculated terminal upward velocities of the order of 1600 km./sec., and has suggested naturally an application to the displaced absorption lines in the spectra of Novæ. Here work remains to be done—and *Nova Herculis* 1934 may well provide some necessary material—in comparing the profiles and intensities of the composite bands of absorption and emission with those indicated by theory. The first steps on the theoretical side have been taken by Chandrasekhar, and on the observational side by Beals, Gerasimovič, O. C. Wilson, and E. G. Williams, but much more remains to be done. There still remains unexplained, for instance, W. H. Wright's discovery that the observed displacements of absorption lines in *Nova Geminorum* 1912 varied as $a\lambda + b\lambda^2$, or the velocity increased with the wave-length ; also the agreements and disagreements of the velocities of ejection of different elements calls for explanation. These are amongst the still outstanding problems in any theory which explains the spectra of Novæ ; Milne's theory supplies the most hopeful line of approach.

Similar questions as to the motions of atoms of different elements under varying radiation pressure can be asked in connection with an application of his theory made by our medallist to account for the outward motions of prominence matter. Here again final conclusions have hardly been reached. S. R. Pike, whose early death was a sad loss to our science, made a brilliant application of his theory to explain the horizontal motion of matter near sunspots, known as the Evershed effect. Beals again has applied the theory of the ejection of high speed atoms to explain the broad bright bands of the Wolf Rayet stars, while Chandrasekhar has examined the theoretical profiles of the bands both for these stars and for Novæ. But to-day we are concerned with Milne's own pioneer work rather than with the fruitful discussions which it has stimulated. For that reason I must refrain from discussing these papers and must also leave on one side Chandrasekhar's theory of the chromosphere, which takes its start in Milne's theory of radiative equilibrium in a modified form.

So far we have been dealing mainly with upper layers in the stars' atmospheres—the upper chromosphere in monochromatic radiative equilibrium and the reversing layer where general radiation pressure to some extent augments selective radiation pressure. We now proceed further into the interior of the star and examine the photosphere, a region in local thermodynamical equilibrium. Here matter in equilibrium at temperature T emits the same radiation as if it were enclosed in a uniform temperature enclosure

at temperature T. Milne has studied this layer in a series of papers, but we may confine our attention to his Bakerian lecture, delivered in 1929, on "The Structure and Opacity of a Stellar Atmosphere." * The main objectives of this paper, in so far as it breaks new ground from the investigations already discussed, may be taken as the determination of the absorption coefficient for photospheric material in terms of the electron pressure and the temperature ; also as consequent results the study of the temperature gradients in the stars, the thickness of the reversing layer, and the optical depths at which absorption lines originate. In discussing the results obtained from a study of the line-strengths of a number of elements in the spectra of a giant star and a dwarf star—Capella and the Sun—Milne states that the figures he derives would require recalculation if the atmospheres contained a considerable proportion of neutral atoms, *e.g.* hydrogen. As all the evidence of recent and later work has tended very largely to increase the estimates of the abundance of hydrogen in stellar atmospheres, we need not follow here all the detailed conclusions of this paper. Later developments of other workers—notably Russell and Unsöld—have modified the original results, but it cannot yet be said that theory and observation are in complete accord. Of both lines of work we may truly say with Milne : "The various unknowns will be entangled with one another in increased complication. But this simply lends an increased attractiveness to the whole subject."

I have mentioned already that Pike demonstrated that the downward flow of prominence matter into a sunspot would be accompanied by a horizontal motion. Milne has developed a most attractive theory on the structure of sunspots and on the circulation therein ; the gases rising up the centre of the spot, expanding and cooling adiabatically, spread outwards and descend again. Velocities of outflow of the observed order are obtained with a model giving a depth for the circulating spot of the order of 100 km., and a drop of temperature due to the adiabatic flow of about 700°. A spot umbra according to this theory is more like a penny in shape than the usual columnar model. It may be regarded as not without interest that Minnaert and Wanders, from a study of spot intensities across the disc, have found that for the visible depths of the spot region convective equilibrium will not fit the facts, but that pure radiative equilibrium fits best. The region of cooling must lie in lower layers inaccessible to our present methods of observational analysis. In a way these critics may be said to be referring Milne back to one of his own main ideas, one to the development of which he owes the award of our medal to-day.

It would be tempting to follow our medallist still further into the depths of the Sun and the stars. But his work in these nether regions lies outside the scope of this address ; the same is true of the work that he has done with reference to the expanding Universe. We must follow him to-day neither to the depths below nor to the heavens above, but we must confine ourselves strictly to that thin stratum of stellar atmosphere which he has made peculiarly his own. Of his more recent work in other realms I will

* *Phil. Trans. Roy. Soc.*, **228** A, 421, 1929.

not say more here than that he has the sympathy of us all in the courageous attacks that he is making on problems of great difficulty. Whether his ideas prevail finally or no, much clarification must result from the discussions to which his independent study gives rise. For Milne's work throughout has proved stimulating to others to a degree rarely found in one so fertile of ideas and so prolific and lucid in expression.

Professor Milne, in asking you to accept this medal from the Royal Astronomical Society, let me beg you to accept also our heartiest wishes for many years of good physical health and of continued successful mental activity. We hope that you may have a long future before you in which you may make many further notable contributions to the science which we all love.

Address delivered by the President on the Award of the Jackson-Gwilt Medal to Mr. W. F. Gale for his Discoveries of Comets and for his Work for Astronomy in New South Wales.

The Jackson-Gwilt Medal and Gift are awarded for the writing of an astronomical work or memoir, the invention or improvement of an astronomical instrument, the discovery of a new Heavenly Body or the promotion in any other way of the Science of Astronomy. The award this year is made to Mr. Walter Frederick Gale for his discoveries of comets and for his work for astronomy in New South Wales.

It is forty years ago since Mr. Gale made his first discovery of a new comet, when, with a 3-inch telescope, he discovered Comet 1894 *b*, or as it was then called 1894 II. Eighteen years later on 1912 September 8 he discovered Comet 1912 *a*, an object of the sixth magnitude visible to the naked eye. Again in 1927 he discovered Comet 1927 *f*; this comet was of the eighth magnitude and was detected with the aid of a pair of binoculars.

The discovery of as many as three comets by one individual implies many nights of assiduous observation over a long term of years. Mr Gale is to be congratulated on the successful outcome of his labours.

The Council have added as one of the grounds of their award the work done by the medallist for astronomy in New South Wales. Since 1886 Mr. Gale has been an active amateur astronomer, and in 1894 he helped largely in the formation of the New South Wales branch of the British Astronomical Association. He was its first Secretary, he has served on its Committee throughout, and he has acted as its President on several occasions. He has helped to popularise the science in New South Wales by numerous lectures and he has maintained a spirit of friendly comradeship among observers in his own and neighbouring States in the Commonwealth of Australia. He has also done good work in observing Mars at several southerly oppositions.

The President then handed the medal to Professor Fowler, addressing him as follows :—

Professor Fowler, in asking you to convey the medal and gift to Mr. Gale, may I ask you at the same time to offer him the congratulations of the Fellows for the work that he has already done and our hopes that he will have health and strength for many more years to forward the cause of astronomy in the southern hemisphere and especially in New South Wales.

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The following Fellows were elected as Officers and Council for the ensuing year:—

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